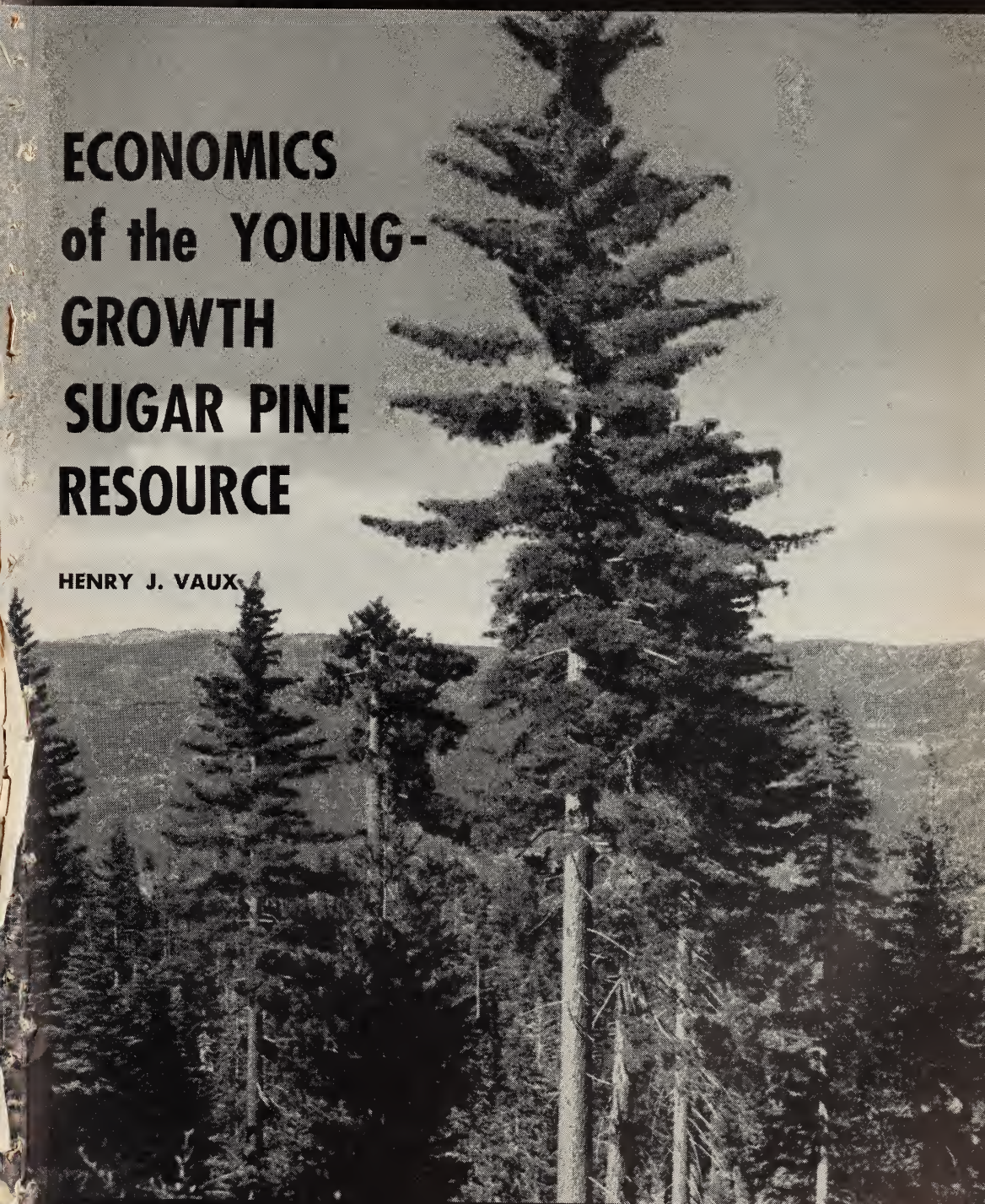




Division of Agricultural Sciences
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ECONOMICS of the YOUNG- GROWTH SUGAR PINE RESOURCE

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THIS BULLETIN is intended for sugar pine land owners, for timber managers, and for those concerned with the formulation and execution of public forest policies, particularly on blister rust control and the encouragement of timber growing.

The point of view emphasizes general economics of the sugar pine situation rather than individual timber growing. But in the mixed public and private economy which characterizes timber production in the sugar pine area, the interdependence of public and private economic activities is so marked that both public and private considerations must be recognized in any realistic appraisal of the situation. As a result, the findings are of interest and significance to all concerned with the sugar pine situation regardless of the specific orientation of that concern.

The study shows that economic use of available resources will require effective sugar pine management on those areas which are highly productive for this purpose. There, the prospects for economic return are great enough to justify the relatively high costs of management. Elsewhere, site conditions, existing stocking, or the difficulty of protecting sugar pine are likely to render maintenance of the species not worth while in the light of prospective returns. Criteria are provided for judging which lands should be managed for sugar pine and which should not be so managed.

The bulletin concludes with comment on existing public policies aimed at promoting sugar pine growth. The need for careful integration of such policies and for emphasis on the central objective—growing sugar pine—is stressed.



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SUGAR PINE is one of the most valuable trees growing in California. Indeed, it has been described as the most remarkable of all pines from the standpoint of both economics and general interest.

But it is a more difficult tree to grow than most commercial timber species found in the state. Its regeneration may be more difficult than that of other species. Without silvicultural help, young sugar pine often does not grow well in competition with other trees. It has special hazards—notably the white pine blister rust—which threaten its survival.

In view of these obstacles to sugar pine growth, many foresters and land owners wonder whether growing sugar pine should be attempted in California. Are the obstacles so great that the effort is not worth while?

Those concerned are faced with a number of possible alternatives. If they do nothing about sugar pine, eventually the resource is likely to dwindle to insignificant proportions as uncontrolled natural forces work themselves out. Or, if they undertake efforts to maintain the resource by special management measures, the scope of these efforts could conceivably vary from doing practically nothing all the way to the formidable job of trying to maintain sugar pine wherever it now grows. The practical problem is to determine, within this wide range, the

objective of private and public sugar pine management policies.

This question is of concern to both public and private owners of sugar pine land and to a variety of public agencies involved in programs of resource protection. Moreover, the nature of the problem makes it essential that the several parties at interest coördinate their objectives. Neither the private owners nor the state or federal governments can solve the problem independently, or even establish satisfactory management objectives for their own lands without considering what role the other concerned groups are going to play.

For this reason, an economic analysis of the sugar pine problem must be framed in terms of the entire resource and of all the agencies concerned. The economy of sugar pine production on private land will depend heavily on whether or not public disease-control programs on such land are continued. The wisdom of continuing such programs will depend in part on whether or not individual private owners want to grow sugar pine. The extent to which national forests should be managed for sugar pine will depend in part on what action is taken on state and private lands. What is done in California must be decided in the light of Oregon's potential position in the sugar pine economy. In view of

this high degree of interdependence between diverse public and private interests, the first problem for economic analysis is that of determining a sound management objective for the sugar pine resource as a whole.

The present study considers this problem primarily as it relates to existing young-growth sugar pine areas—the areas where the economic effects of alternative sugar pine management policies will first be felt. It attempts to provide guidance in what the objective of management on such sugar pine lands ought to be, if the economy of the sugar pine

region is to obtain the maximum economic advantages from the presence of this resource.

The central question to be answered is: “Under what circumstances is it economic to undertake the special silvicultural measures needed to produce a sugar pine crop from young-growth stands now more or less stocked with the species?” Closely related to this are the questions of how big a sugar pine supply the American economy is likely to need in the future, and of what particular forest tracts can produce such a supply most economically.

SUGAR PINE RESOURCE

General characteristics

Sugar pine (*Pinus lambertiana* Dougl.) is one of three commercially important five-needle pines native to the United States. From the day of its discovery by David Douglas in 1826 (Harvey, 1947), the tree has been of major interest to botanists, lumbermen, foresters, and recreationists. Along with the northern white pine of the eastern United States and the western white pine of the Inland Empire, it provides the soft, straight-grained, easily worked timber commonly known as “white pine.”

Appearance. In virgin stands, sugar pine is the monarch of all the pines, sometimes exceeding 200 feet in height and 10 feet in diameter. Mature trees are recognized easily by their huge cones, which often exceed 15 inches in length, and by their red-brown, scaly bark. Veterans in the stand have flat tops and a distinctive branching habit which results in one or two rather straight horizontal limbs which are considerably longer than the remaining limbs in the crown (Jepson, 1910).

Younger trees grow in straight, symmetrical form with rather narrow crowns. The bark is pale gray and smooth in youth, gradually becoming darker colored and rough in appearance. The

needles, which are 3 to 5 inches long, are borne five to the fascicle. This arrangement of the needles serves to distinguish sugar pine from all other commercial pines within its range with the exception of western white pine. Young sugar pines and western white pines are very similar in appearance. They can be distinguished most readily by reference to the lower altitudinal range of sugar pine, and by the fact that its needles are stiffer than those of western white pines and are often twisted (Harlow and Harrar, 1950).

Growth habits. In youth sugar pine grows moderately rapidly and maintains this growth rate longer than do most species. Normally sugar pine occurs in mixture with other timber species characteristic of the forests of the Sierra Nevada, the southern Cascades, and the inner Coast Ranges. Among the most important of these associates are the true firs, ponderosa pine, Jeffrey pine, Douglas fir, and incense cedar.

Wood. As a raw material, the wood of sugar pine is soft, easy to work, and under changing atmospheric conditions shrinks or swells less than most other softwoods. For these reasons, sugar pine has always been highly prized in the lumber trade. Its market extends into every



Fig. 1. The commercial range of sugar pine in California and Oregon.

major lumber-consuming region of the United States, and to many foreign countries. Its technical properties, its markets, and the end uses to which it is put are all very similar to those of the two other American commercial soft pines, eastern white pine and western white pine.

The tree is named from the sugary exudation which forms hard, white, crystalline nodules on the upper side of wounds in the wood. This substance "is as sweet as cane sugar, but belonging to a different class of sugars, namely pinite or pine sugar." (Jepson, 1910.)

Recent chemical investigations show that sugar pine heartwood contains about 4 per cent pinitol (the currently accepted name for pine tree sugar). Crude pinitol can be extracted readily from the wood. The substance may prove useful in industry as a raw material for synthesizing chemical compounds. But commercial exploitation will require further study of processing methods and market potentialities (Anderson, 1952).

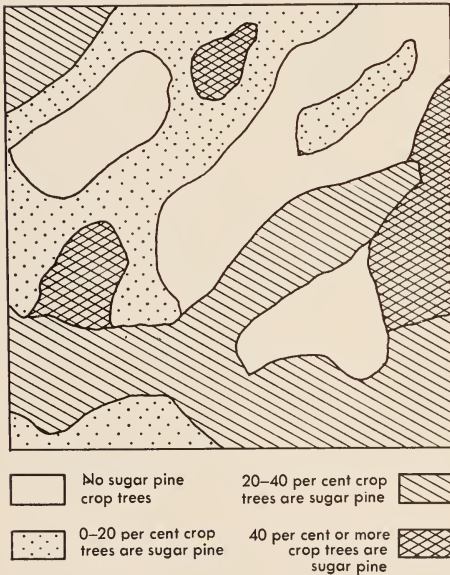


Fig. 2. Typical irregular distribution of sugar pine crop trees in 160-acre tract of young-growth, mixed conifer forest.

Range and occurrence

Range. Although sugar pine grows as far south as Lower California and northward almost to Mt. Hood, its commercial range (fig. 1) is more restricted. On dry, south- and west-facing slopes it occurs in mixture with ponderosa pine. More commonly, it is found on benches and north slopes mixed with white fir and red fir. Near its northern commercial limit it may be found at elevations as low as 2000 feet. Merchantable stands extend up to 4000 feet elevation in the north and to 7000 feet in the south (Sudworth, 1908).

Occurrence. In the virgin forest, sugar pine occurred in significant amounts over an area of $5\frac{1}{2}$ million acres (U. S. Bur. Entomology and Plant Quarantine, 1951a). However, true sugar pine types (that is, areas in which sugar pine is the key species and where it forms 15 per cent or more of the stand by volume) were limited to about $3\frac{1}{2}$ million acres. Fire, logging, and reservations for park and similar purposes have considerably reduced the area of land available for sugar pine production.

Today, something over 2 million acres of commercially available land support at least some sugar pine growing stock. (Commercially available land is forest land which is: 1) producing or capable of producing usable crops of wood; 2) economically accessible for timber growing either now or prospectively; and 3) not reserved for uses other than timber production.) A large part of this area, including much of the best sugar pine land, lies on the western slope of the Sierra Nevada, between Mt. Whitney and Mt. Shasta. Over three fourths of the commercial sugar pine land is in California. The remainder is in southern Oregon.

The sugar pine forest does not occur as a continuous unbroken stand. It is distributed in tracts of varying size within the matrix of the pine, mixed conifer, and

true fir forest types (fig. 2). Depending on topography, past history of the forest, and other local conditions, these tracts may vary in extent from a few to several hundred acres. This "patchy" occurrence of the species creates special problems both in studying the sugar pine situation and in devising suitable measures for handling it.

Problems of growing sugar pine

Sugar pine presents problems peculiar to California forestry. Forty years of experience have shown that such methods of cutting as tree selection, seed tree cutting, and clear cutting in large blocks, although successfully used elsewhere, are not well adapted to the forest types in which sugar pine occurs (Hallin, 1951). Thus, in part, the problem of growing sugar pine is identical to the problem of managing mixed conifer forests in the whole Sierra region. (Problems of growing sugar pine in the Sierra Nevada differ in some important respects from the problems of growing sugar pine in southern Oregon. In parts of the latter state clear cutting in larger blocks and greater use of seed-tree techniques may be feasible.)

In addition, sugar pine has characteristics which often make it more difficult to grow than other species which compete with it in the forest stands. It is highly susceptible to white pine blister rust (*Cronartium ribicola* Fisch.). Thus, the forest management measures applied to a stand must be designed with these characteristics in mind if a satisfactory crop of sugar pine is to be grown. The nature and importance of these measures can be made clear by a more detailed discussion of the tree itself.

Reproduction. Sugar pine produces bumper crops of seed at six- to eight-year intervals. Although considerable quantities may fall in intervening years, the seed is highly palatable to rodents, which dispose of enormous quantities of it before it has a chance to germinate (Fowells

and Schubert, 1951). The seeds are large and, hence, dissemination is likely to be satisfactory only within a radius of 150 feet from the parent tree (Dunning, 1949). A mineral soil seedbed is essential for satisfactory establishment of the seedlings. Once established, the young trees are persistent and quite tolerant for a number of years. Planting stock can be produced successfully in forest nurseries. However, survival has been poor in some sugar pine plantations, and improvements in nursery and planting techniques are being studied.

Growth. Sugar pine grows rather rapidly. Moreover, it maintains rapid growth for a longer period of years than its associates (Baker, 1934). For this reason, second-growth mixed conifer stands with a substantial proportion of sugar pine in the growing stock yield somewhat higher timber volumes than do stands of equal age and density which do not contain sugar pine (Dunning and Reineke, 1933). As a result of this more persistent growth, sugar pines may reach a given merchantable diameter at a somewhat earlier age than do other species. This advantage is offset (at least in part) by the fact that, in its early years, sugar pine height growth may be less rapid than that of its more aggressive competitors, particularly white fir. Until the trees reach an age of fifty to sixty years, the height growth of the firs may exceed that of the sugar pines. This results in suppression of the pines unless they are favored by release cuttings. This adverse competition from the firs seems to be of greatest significance in the southern portion of the sugar pine range. In northern California and Oregon, sugar pine seems able to compete more effectively in height growth throughout its life. Indeed, in the Umpqua Basin in Oregon, sugar pine seems to outgrow its nearest competitor, Douglas fir, by a substantial amount.

Fire. Young-growth sugar pine is somewhat more resistant both to direct heat killing and to crown injury by fire

than are the firs (Show and Kotok, 1924). But even moderately hot ground fires may kill a significant part of the sugar pine growing stock or reduce growth by damage to crowns. Careful protection of established young-growth stands is therefore essential.

Nevertheless, even casual inspection of old-growth mixed conifer forests suggests that fire has probably played a key role in the past in maintaining sugar pine as a major component of the virgin stand. Fires have apparently favored establishment of sugar pine seedlings at the expense of potential fir competition. It also seems probable that fire exclusion has served to increase very materially the amount of fir in the understory of old-growth mixed conifer types. As a result, when such stands are logged, the pre-established fir may effectively block the development of new pine regeneration (Baker, 1934).

Insects. The mountain pine beetle (*Dendroctonus monticolae* Hopk.) is the most destructive insect enemy of sugar pine. It prefers living timber, and endemic losses are more or less continual (Keen, 1928). During recent years this pest assumed a new and serious role when, for the first time, it was observed killing vigorous young-growth sugar pines at several points in the western Sierra (U. S. Bur. Entomology and Plant Quarantine, 1952). Danger from the beetle seems to be greatest in those young-growth stands having the biggest proportion of sugar pine in the species mixture. Due to the very recent development of losses in young-growth stands, full evaluation of the seriousness of this insect hazard and of measures to combat it must await further study.

The sugar pine cone beetle (*Conophthorus lambertianae* Hopk.) is also of apparent significance wherever problems of sugar pine regeneration arise (Miller, 1915). This insect invades the cone stalk at the beginning of the second season of its growth and effectively prevents seed

development. In view of the critical role of the seed supply, already described, the cone beetle may prove to be a very significant factor in the problem of sugar pine regeneration.

Disease. The principal disease affecting sugar pine is the white pine blister rust (*Cronartium ribicola* Fisch.). The rust entered California in 1936 and has since been observed as far south as Amador and San Mateo counties. It is evidently only a matter of time before the disease is established throughout the sugar pine range. The disease kills saplings and small poles quickly and, under favorable conditions, eventually destroys the entire sugar pine component of the stand. However, large trees (those 20 to 30 inches d.b.h. or larger), and those on sites unfavorable for rust development may escape serious damage (see fig. 3).

The threat of blister rust is thus aimed primarily at young-growth sugar pine and at the advance reproduction which has become established in overmature stands. The degree of hazard is related to moisture conditions—very dry sites are unfavorable to rust development, wet sites favorable to it. In view of the brief experience with the disease in California, measurement of the hazard must be general rather than specific. From data now available, the relationship between hazard conditions, tree size, and expectation of sugar pine survival is shown in figure 3.

Although part of its life is spent on five-needle pines, blister rust cannot spread from pine to pine. It must complete its life-cycle on one of the alternate hosts, currants or gooseberries (*Ribes* spp.). The principal ribes associates of sugar pine are Sierra gooseberry (*R. roezli*) and Sierra currant (*R. nevadense* Kell.), both highly susceptible to blister rust (Quick, 1951).

Under present practice, sugar pine is protected by eradicating ribes plants in the vicinity of sugar pine trees. As the spread of the disease from ribes to pine

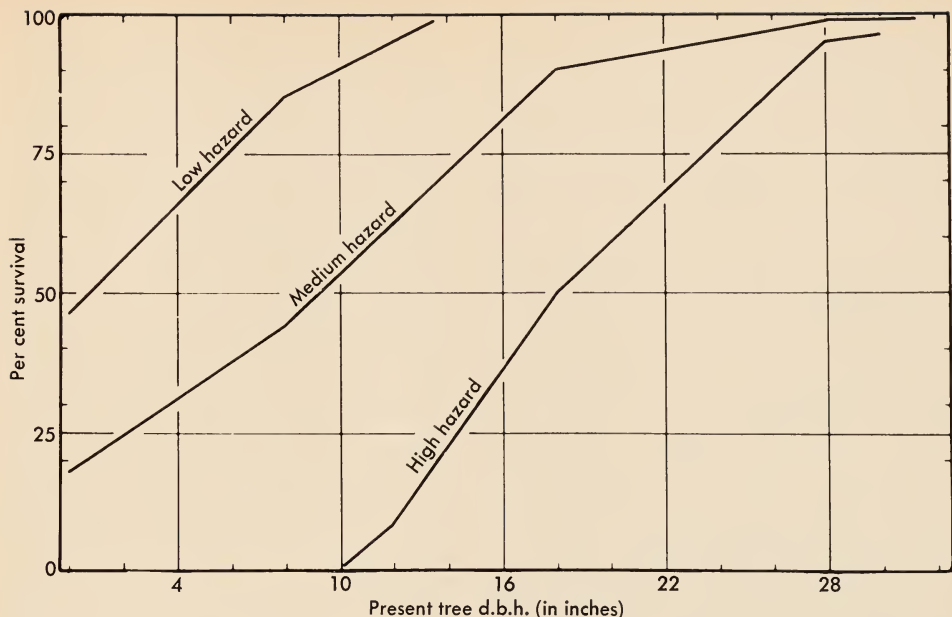


Fig. 3. Sugar pine survival, related to degree of rust hazard and to size of tree. "Per cent survival" shows proportion of sugar pines which will not be killed by blister rust under the indicated conditions of hazard and tree size. Source: Based on data furnished by U. S. Bur. Ent. and Plant Quarantine.

is limited to relatively short distances under most conditions, protection can be obtained by eradicating ribes from the sugar pine area and from a comparatively narrow *sanitation strip* around it. Experience to date indicates that where adequate protective measures are taken sugar pine losses due to the rust can be held to negligible levels.

Basis for management. In the past, those not directly concerned with it have often assumed that blister rust control was the heart of the sugar pine problem. To assume this is to oversimplify the situation. A typical sugar pine area, protected from the rust, may still yield very little sugar pine because other management measures have been inappropriate. Having noted this, we should also recognize that the problems of growing sugar pine, although important and perhaps not yet fully understood, differ only in detail and degree from the general problems of forest management in the mixed

conifer types. These problems need not cause us to conclude that sugar pine silviculture is a hopelessly difficult enterprise. On the contrary, with the exception of blister rust, all of the factors discussed above operated in the virgin forests, where Nature's management system produced highly successful sugar pine crops.

The basic conclusion which does seem to follow from the foregoing outline of sugar pine characteristics is this: Successful management for sugar pine will require recognition of the peculiar habits of the species and careful adaptation of forest practices to its requirements. Blanket rules of forest treatment are likely to prove an unsatisfactory substitute for the informed judgment of the trained forest manager, intimately familiar with his stand, and applying his knowledge directly to local forest conditions as he observes them in the field.

In many young-growth sugar pine areas this will mean thinning the stand

to curtail competition with sugar pine crop trees, pruning to improve quality (see page 28), controlling blister rust, or using other special measures to favor sugar pine. The cost of raising the sugar pine crop under these conditions of management is considered later (see page 25).

Sugar pine areas, ownership, and volumes

Areas. The mixed conifer, pine, and fir forest types, of which sugar pine is often a prominent feature, occupy 10.1 million acres of commercial forest land in California (Wieslander and Jensen, 1946). Much of this area never supported significant amounts of sugar pine, and from some of the area that did, the pine has been more or less permanently removed by fire, logging, or other agencies. As a result, the estimated area of forest

land available for commercial sugar pine production is 2,138,000 acres. This includes lands in both California and Oregon, but excludes those sugar pine areas permanently withdrawn for national parks, recreation areas, or other noncommercial uses. Estimates of the distribution of this area, by states, by ownership, and by cutting status are shown in table 1.

Ownership. Of the available sugar pine land, 77 per cent is in California. Forty seven per cent of the total has already been cut at least once. Thus the young-growth stands to which this study is ultimately directed account for roughly half of the total sugar pine land resource. Private owners hold title to 44 per cent of the total acreage and to 54 per cent of the cutover land. These private holdings are of even greater economic importance than the percentages suggest

Table 1. Estimated Area of Forest Land Available for Commercial Sugar Pine Production, by Stand Condition and by Ownership, 1950*
(Area in thousands of acres)

Cutting status	Ownership		
	Federal	State and private	Total
California			
Cutover.....	382	419	801
Uncut.....	474	376	850
Total.....	856	795	1,651
Oregon			
Cutover.....	93	124	217
Uncut.....	235	35	270
Total.....	328	159	487
Total—Sugar pine region			
Cutover.....	475	543	1,018
Uncut.....	709	411	1,120
Total.....	1,184	954	2,138

* Source: U. S. Bur. Entomology and Plant Quarantine, Off. Blister Rust Control.

because they include lands of better-than-average productive capacity.

Volumes. The merchantable volume of sugar pine timber approaches 21 billion board feet. About 2 billion feet are in recreation areas or are otherwise unavailable. The economic standing timber resource thus amounts to 18.8 billion board feet (table 2). About 47 per cent of this is on private land with the balance largely in national forests. More than 92 per cent of the standing timber volume is in California.

For young-growth stands, merchantable timber volumes as just described are not an accurate indicator of economic potential. A large percentage of the growing stock on such areas is too small to be reflected in merchantable volume. Table 3 shows the character of growth on the cutover areas in terms of the existing quantity of sugar pine stocking. The stocking index used is number of crop trees per acre. A crop tree is defined as a dominant sugar pine, of good health, quality, and growth rate, that will remain dominant until the end of the rotation in the face of whatever competition is now evident (U. S. Forest Service, *et al.*, 1952).

A notable feature of table 3 is that over half the acreage of sugar pine cutover land is very sparsely stocked with sugar pine. Even with better than average site conditions and careful management, stands with this degree of stocking will yield less than 2 M board feet of sugar pine per acre when the existing growing stock matures. On the other hand, the bulk of the well-stocked land is Site class II (see table 3, footnote 2, for basis of site classification) or better. The productive potential of such areas is excellent and will permit the growing of substantial sugar pine volumes.

Method of analysis

If the young-growth sugar pine resource is to be so used as to make maximum contribution to the economy of the region, the objective of management must be to extend efforts to grow this species just to the point where the additional returns from sugar pine production are offset by the additional costs which are incurred. Accordingly, we will begin our analysis with a look at potential sugar pine markets, turn to the costs of providing sugar pine supplies, and then,

Table 2. Estimated Volume of Available Sugar Pine Sawtimber, by Subregion and Ownership, 1946*
(Volumes in million board feet, log scale)

Subregion	Ownership		
	Private	Public†	All ownerships
California			
West Sierra Pine.....	5,387	7,330	12,717
East Sierra Pine.....	927	418	1,345
Other areas.....	1,337	1,978	3,315
Total.....	7,651	9,727	17,378
Oregon.....	1,120	253	1,373
TOTAL.....	8,771	9,980	18,751

* Sources: California Forest and Range Experiment Station and U. S. Bur. Entomology and Plant Quarantine, Off. Blister Rust Control.
† Ninety-five per cent of the publicly owned sugar pine is in national forests.

Table 3. Estimated Area of Cutover Sugar Pine Land in California* and Oregon, by Site and by Density of Present Sugar Pine Stocking† (Area in thousands of acres)

Site Quality‡	Sugar pine crop trees per acre					
	14 or more	10-13.9	6-9.9	2-5.9	Less than 2	Total
A-200.....	3.8	2.4	3.6	6.1	19.3	35.2
I-175.....	70.2	32.9	53.3	59.6	204.3	420.5
II-150.....	39.3	29.1	43.1	74.4	199.3	385.2
III-125.....	15.0	12.4	23.0	34.5	92.1	177.0
All Sites.....	128.3	76.8	123.0	174.6	515.0	1,017.9
Percentage.....	12.6	7.5	12.1	17.2	50.6	100.0

* Approximately 80 per cent of the total area is in California.

† Source: U. S. Bur. Entomology and Plant Quarantine, Off. Blister Rust Control.

‡ Site quality used is Dunning's Site Classification based on age of dominants at 300 years, determined in young-growth stands by reference height-age curves appearing in Dunning, D., "A site classification for the mixed conifer selection forests of the Sierra Nevada," Calif. Forest and Range Exp. Sta. Research Note No. 28. Berkeley, 1942.

Note: Totals may not add because of rounding.

in the light of these considerations, formulate a sugar pine production goal. The study concludes with a discussion of how this goal might best be met, in terms of

the area which should be devoted to sugar pine production and of the public and private policies which might be needed.

POTENTIAL MARKETS AND VALUES

We noted earlier that under conditions now generally prevailing in sugar pine forests, most old-growth trees would survive until harvested. In the absence of special measures favoring sugar pine, losses will occur in the younger trees, and it is the value of these which primarily concerns us. Because sugar pine typically occurs in mixture with other species, values for watershed protection and recreation do not appear to be at stake except in local areas. The protective functions of most forests would not be substantially impaired even if all of the sugar pine in them were to succumb to blister rust. (Some ecologists are convinced that maintenance of a mixed species stand has significant advantages from the standpoint of the biological

health of the forest. As it is currently impossible to quantify effects of this kind, they have been disregarded in the subsequent analysis.) Some recreational values will be lost when the majestic, overmature sugar pine—"Queen of the Sierras"—disappears from the stand. But, except in recreation areas which are reserved from cutting, these old-growth trees seem destined to disappear during the next half century, regardless of whether or not special sugar pine management measures are undertaken.

Accordingly, the question of the values at stake in sugar pine on commercial forest land centers on the market for wood products made from sugar pine. Of particular significance will be the market fifty to one hundred years hence,

when currently jeopardized young-growth trees have become mature.

Consumption

Sugar pine markets are of great economic importance. For the period 1949 to 1951, sugar pine lumber production averaged more than 400 million board feet per year (U. S. Bureau Census, 1952). More than four fifths of the total production was in California. Although sugar pine is also used for the manufacture of plywood, veneer, and shakes, lumber is of overwhelming relative importance, accounting for more than 98 per cent of the total volume of use (Burks, Vaux, *et al.*, 1948). The total requirement for all other purposes is usually less than 5 million board feet per year. Thus, in discussing sugar pine values, we are concerned almost entirely with those derived from the production of sugar pine lumber.

As statistics of timber consumption are not ordinarily compiled in the United States, the best available measure of the volume of sugar pine use is provided by lumber production data. These are shown in figure 4 for the period 1899 to 1951. It is apparent that sugar pine use has followed a rising trend over the last half century, but that consumption has fluctuated very widely around that trend, particularly during the last three decades. Is there reason to suppose that either the rising trend or the apparent instability in the level of use will continue to characterize the sugar pine industry? To answer this question we need to look more in detail at the uses of sugar pine and at the factors shaping the historical consumption pattern.

Uses of sugar pine lumber

Sugar pine lumber goes into three broad types of end use: light construc-

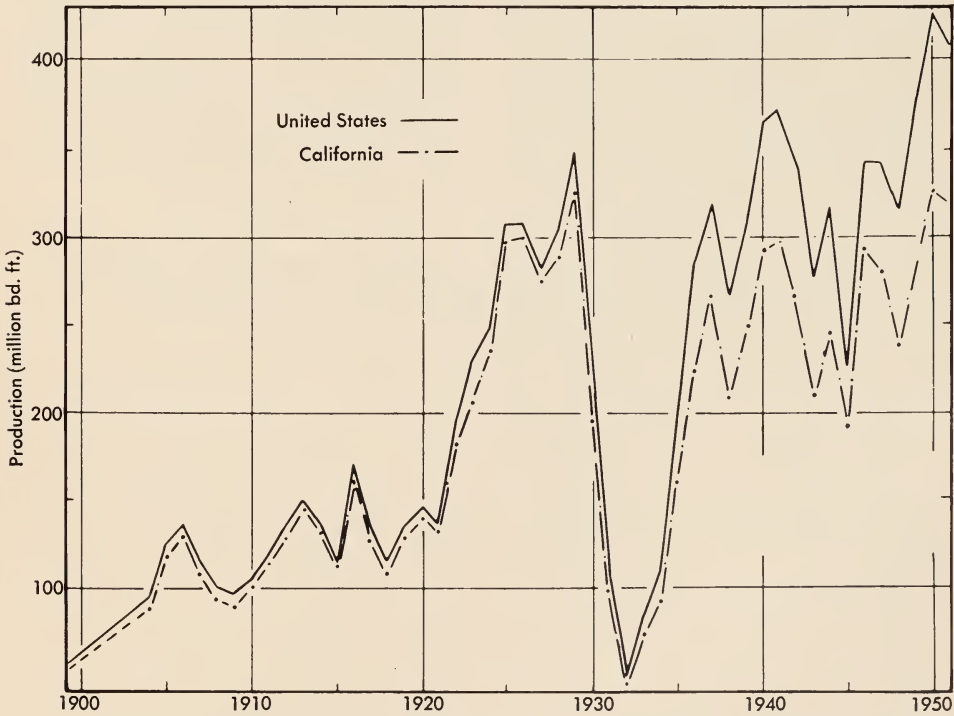


Fig. 4. Sugar pine lumber production in the United States and California, 1899 to 1951.
Source: U. S. Forest Service.

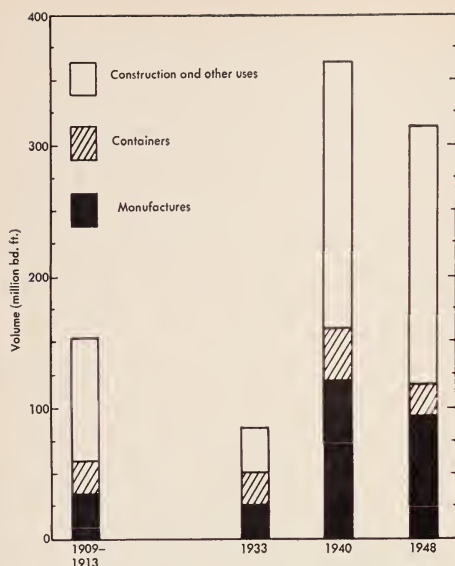


Fig. 5. Changes in sugar pine use, 1909 to 1948. Source: U. S. Forest Service.

tion, containers and shipping lumber, and manufactures. The latter classification includes manufacture of a wide variety of products, such as patterns, millwork, instruments, and fixtures (Merrick, 1951).

The relative importance of these different classes of use changes with market conditions. In years of moderate or high

rates of construction, about 60 per cent of sugar pine consumption is for building (fig. 5). But the relative importance of this use may be far less in years of low construction activity. The pattern has also changed with the passage of time. Between 1910 and 1948, manufactures became relatively more important as an end use and containers less so.

Much of the stability in the pattern of use displayed in figure 5 probably occurs because of the nature of lumber production. Sugar pine lumber is not a simple, homogeneous product. It consists of a mixture of a variety of different sizes and grades of lumber which may differ markedly in their usefulness for different purposes. About a third of the lumber produced from a representative old-growth sugar pine stand is Shop and Select grade material (Brundage, Krueger, and Dunning, 1933). The remainder is Common grade lumber. Because much of the latter is not technically suitable for specialty manufacture, it is used in the construction and container markets, where quality is of less importance than in manufactures. In a sense, it is a by-product of the production of high-quality sugar pine lumber.

Table 4. Average 1950 Prices* of Select and Shop Lumber, f.o.b. Mill, for Sugar Pine, Ponderosa Pine, and White Fir in the Western Pine Region†

Grade	Price per M bd. ft.			Price as per cent of sugar pine price	
	Sugar pine	Ponderosa pine	White fir	Ponderosa pine	White fir
B and Better Select.....	\$ 244.24	\$ 219.97	\$	90.1	....
C Select.....	235.36	204.14	146.69‡	86.7	62.3
D Select.....	209.69	177.52	122.33	84.7	58.3
1 Shop.....	131.13	114.92	94.41	87.6	72.0
2 Shop.....	94.75	87.52	71.02	92.4	75.0
3 Shop.....	68.38	65.41	59.31	95.7	86.7

* Prices are averages of all sizes within each grade, weighted by the volume of each size sold.

† Source: Western Pine Association. 1950 yearly summary of past sales. Portland, Oregon, 1951.

‡ C select and better.

The economic importance of these upper grades is emphasized by the data of table 4. These show the relationships between prices per M board feet, at the mill, of the various grades of sugar pine lumber. The premium commanded by Clear grades is apparent. Shop grades share in this advantage pretty much in proportion to the extent of the clear material which can be cut from such grades. The data also show clearly the differences in value at the mill between sugar pine lumber and that of the other principal species which occur with it in the mixed conifer forest.

The effect of eliminating sugar pine from the manufacturing market would be quite different from the effect of eliminating it from the construction and container markets. In the two latter areas, sugar pine competes with a wide variety of other species of softwood lumber. It is a very minor element in these markets. It accounted for less than 1 per cent of all softwood lumber used for containers and for construction in 1948. Even in the Pacific Coast market, sugar pine remains both a minor component of supply for these markets and one which could readily be replaced by other species.

On a quantity basis, sugar pine occupies only a slightly more impressive position in manufacturing markets. There, it accounted for a little over 2 per cent of all softwoods used in 1948. But this total figure obscures the fact that the manufacturing market represents an aggregate of a number of rather diverse industries. In some of these, sugar pine plays a very important role. The ultimate measure of the value of the species thus depends on its significance for those particular industries for which it has especially desirable properties. Before analyzing them in detail, however, we must consider more carefully the extent of market competition between sugar pine and other species of softwood lumber, particularly as it relates to this specialty market.

Substitutes

Sugar pine lumber has technical properties which are very similar to those of western white pine and eastern white pine. Lumber of these three species is characterized by easy workability, dimensional stability, and softness. Because of the long period over which it has been marketed, eastern white pine is perhaps the best known to consumers, but both western white pine and sugar pine are now recognized as having comparable properties. In other words, the three species are close substitutes. As a group, these three soft pines are clearly distinguishable from the hard pines (such as the southern pines) whose properties are quite different. In most manufacturing uses there is little competition between these types of lumber. However, old-growth ponderosa pine, which belongs botanically to the hard-pine group, has many of the characteristics of softness and workability found in the soft pines. For some purposes, it provides a good substitute for the white pines, but for other purposes it does not.

White pine. The extent to which the white pines dominate certain softwood manufacturing markets is shown in table 5. The three white pines currently provide only about 6 per cent of the total softwood lumber supply. But in each of the industries indicated in the table, white pines account for more than 6 per cent of the softwood used. In other words, these industries *prefer* white pine to other softwood species. In some instances, notably match and boot and shoe manufacture, the preference for white pines is overwhelming. Even in the case of sash, doors, and millwork, where nonwhite pine lumber is widely used, the preference is striking if we remember that the wood needs of this industry substantially exceed the *total* supply of all white pine, regardless of grade. That is, if white pine supplies were larger, more of it would undoubtedly be used in the sash, door, and millwork field.

Table 5. Principal Manufacturing Uses of White Pines and the Dominance of White Pine in Such Uses, 1948*

End use	Sugar pine	Other white pines	Total	Per cent of all softwood use
Million board feet				
Sash, doors, and millwork	66.9	97.9	164.8	8.3
Pattern making	19.5	45.7	65.2	72.0
Boot and shoe findings	0.4	30.6	31.0	95.0
Furniture	0.5	28.9	29.4	9.1
Fixtures	0.6	16.8	17.4	25.1
Shade and map rollers	0.3	11.7	12.0	58.2
Toys	0.3	10.3	10.6	40.2
Ship and boat building	0.2	8.1	8.3	13.2
Signs, scenery, et cetera	0.5	6.6	7.1	18.0
Matches	0	34.2	34.2	98.0
Other specialty manufactures	4.5	61.5	66.0	3.6
Total	93.7	352.3	446.0	13.2

* Source: U. S. Forest Service. Wood used in manufacture, 1948. Forest Resource Report No. 2. Wash., D.C., 1951. (Adapted from its table 16.)

There is evidence to suggest that, as time goes on, the preference for white pine over other softwoods in the specialty market is increasing. Such market preferences are difficult to observe because the available data show only consumption, and this is influenced not only by market preferences but also by conditions of supply. Thus the consumption of white pine, as compared with other softwoods in the manufacturing market, has fluctuated considerably over the past forty years and no definitive trend is noticeable. But during this period the supply of white pine has become generally smaller relative to that of competing softwoods. In order to make allowance for this, figure 6 shows the use (in all manufactures except containers and millwork) of white pine and of all softwoods expressed as a percentage of the total supply of each of these kinds of lumber.

The percentage of all softwood production going into specialty uses has varied somewhat over the period of observation, but the data suggest a level trend. In con-

trast, the proportion of white pine production going into specialty uses shows a marked rise over the last forty years. This suggests that, whatever the absolute size of the specialty market and whatever the supplies available to it, specialty manufacturers tend to absorb an increasing proportion of the available white pine as time goes on. This is consistent with the hypothesis that, as supplies of high-grade softwood timber of all kinds dwindle, white pine becomes increasingly desirable to specialty users.

In 1948 the total use of white pine lumber in the specialty field amounted to 446 million board feet. But only 21 per cent of this was sugar pine. Thus, even if we grant the existence of a sizable specialty market exhibiting a strong preference for white pine, could not the demand be met effectively by western and eastern white pine alone? For a number of reasons the answer seems to be "no." In fact, the future may see the white pine market turn more to sugar pine as a source of supply than it has in the past.

Studies of the economics of the western white pine industry suggest that production of that species cannot be continued at present levels indefinitely. The volume of remaining old-growth and the age of second-growth stands are such that sharp curtailment of western white pine lumber output seems probable within the next thirty-five years (Matthews and Hutchison, 1948). Sugar pine will then be in a strong position to take over part of the western white pine market. Moreover, both population growth and industrial development are shifting the geographic center of the white pine market westward, away from primary areas of eastern white pine supply. The market area in which sugar pine has a comparative advantage over eastern white pine is thus likely to expand materially. The effect of these changes would be to increase significantly the market need for sugar pine. Finally, it may be noted that both eastern and western white pine have been severely attacked by blister rust. These species can be

grown only where intensive protection against rust has been provided. Costs of such protection are almost certain to be at least as high as costs of protecting sugar pine (Matthews and Hutchison, 1948).

Future market conditions

A number of conclusions about the future market for sugar pine lumber seem reasonable in the light of this history of past use. The market with which we are concerned is in the decades following the year 2010. Previous to that date, old-growth sugar pine is likely to continue to dominate the market and most of the managed young-growth stands will not have attained optimum merchantability. But at the end of the next sixty years, most of the commercial old-growth timber of *all species* will have disappeared.

Construction and shipping lumber markets. So far as these markets are concerned, there seems to be little reason for special measures to produce sugar pine. Other species perfectly satisfactory for such purposes can undoubtedly be supplied at costs lower than those for sugar pine. Moreover, the size of each of these market sectors may well be smaller than it is now. Containers made from wood fiber are continuing to displace lumber; they are invading the fruit and vegetable field which comprises such an important element in the container market for western woods. Although the level of construction half a century hence cannot be easily envisaged, curtailment in this use of lumber may take place either as a result of further substitution in the building-materials field or in response to reduced rates of population growth.

Specialty market. In this market the outlook is different. Use of white pine lumber for specialty manufactures was 17 per cent greater in 1948 than it was in 1928. Over the same period, use of

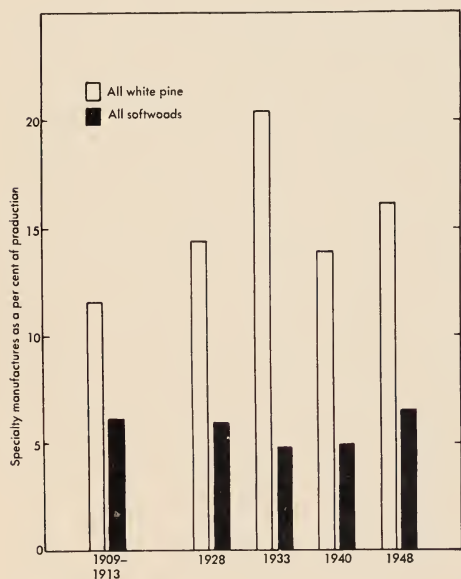


Fig. 6. Proportion of total white pine and softwood lumber production used in specialty manufactures. Selected years, 1909 to 1948.

other softwoods for specialty manufacture had increased only 8 per cent, and softwood lumber consumption in all uses had declined about 1 per cent (U. S. Forest Service, 1928; 1948). Thus, even in the face of some reduction of use for construction and shipping, the market for white pine lumber for specialty manufacture has been well maintained during recent decades. This is a fact of great importance for the future outlook.

The future market. The trend of our national economic development is toward greatly expanded and diversified manufactures. Certain manufacturing industries, now well established, may dwindle in importance, as have the ship- and boat-building and wooden-vehicle industries in the past. Other industries may substitute new materials for lumber, as have automobile and furniture manufactures. But new industries will emerge with new demands for quality raw mate-

rials, and established industries will find new uses for wood. No one can foretell what will happen to wood use in each and every type of manufacture in which the American economy engages. But we can anticipate a major expansion and diversification of those manufactures during the next fifty years. And on the basis of past experience, we may conclude that the demand for high quality white pine lumber will be sustained, as it has been for the past two decades, by this sort of industrial growth.

The history of wood use during the past forty years makes it apparent that white pine will be excluded from many present uses, if supplies of it are allowed to dwindle. But it also suggests that, if supplies are maintained, demand for those supplies will appear.

The experience with eastern white pine is significant in this respect. There, in an area where the forest economy has already matured, we find that manufacturing use of eastern white pine fell to a very low ebb following 1930. Eastern white pine supplies represented less than 2 per cent of total softwood lumber supplies during the Depression. But by 1948 white pine production (largely from *second growth* stands) had recovered substantially and accounted for 4 per cent of total softwood supplies. During the same years, the specialty market expanded its use of eastern white pine by four and a half fold. As shown in figure 7, the growth in eastern white pine use was far more than in proportion to the growth of all softwoods in the same uses. These facts lend support to the conclusion that much of the past decline in eastern white pine consumption is attributable to dwindling supplies, and that, given reasonably plentiful and moderate-priced supplies of the wood, the technical properties of white pine are good enough to attract substantial consumer demand in a diversified and expanding technology.

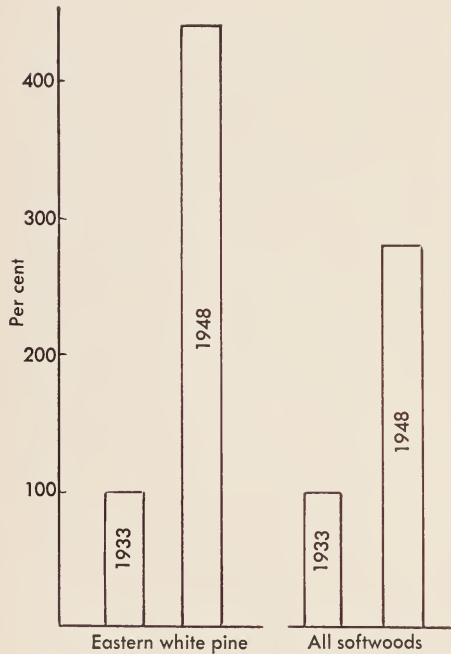


Fig. 7. Relative increase in use of eastern white pine and of all softwoods in specialty uses, 1933 to 1948. Source: Adapted from U. S. Forest Service data.

Market outlook for sugar pine timber

On the basis of the considerations outlined in the preceding sections, we have concluded that sugar pine, along with white pine generally, will continue to command the same sort of market preferences characterizing them in the past. But in order to make further economic analysis of our problem we must quantify this broad general outlook in terms of what it means for sugar pine stumpage. As a basis for this, we may analyze what has happened in the past to sugar pine stumpage consumption, in the light of trends in prices, incomes, and other related factors.

In order to analyze this history, we need a measure of the annual consumption of standing sugar pine timber. As the volume of such stumpage cut in any year is closely correlated with lumber output during that year, we may use the lumber production statistics of figure 4 as an index of consumption of standing timber.

Stumpage price. One important independent variable expected to influence consumption is stumpage price. Figure 8 shows the average price paid for sugar pine stumpage sold each year from national forests in California during the period 1910 to 1949. This series provides the best available data on market value of stumpage used for current consumption. The bulk of the timber consumed during the 1910 to 1949 period was privately owned and thus does not appear directly in the data of figure 8. However, price data for private timber are not reliable indices of current values of timber for consumptive use, because private timber is often sold in large blocks to be held for cutting at a distant future date (Steer, 1938). Prices in such transactions are heavily discounted below the market value for current consumption.

National forest timber, on the other hand, is sold only for immediate cutting. In most areas during the period under discussion, it was sold in markets where private timber was also available to the

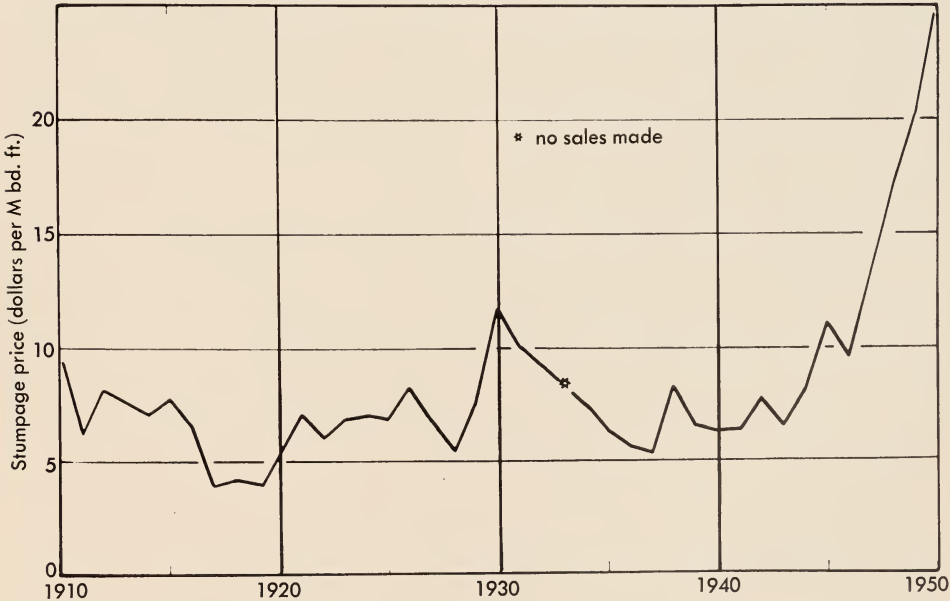


Fig. 8. Average price per M board feet of sugar pine timber sold on national forests in California. (Prices in terms of 1950 dollars.)

purchaser. Although California stumpage markets are at best imperfectly competitive, the degree and kind of competition seem adequate to insure reasonably close correspondence between the series of figure 8 and the current market value of all timber cut for consumption.

Apart from a high degree of instability, characteristic of all timber prices, the most noteworthy features of the price series are the gradual but significant rising trend of real prices from about 1916 to 1946, and the very dramatic upward surge since 1946.

The long-run tendency toward increased values is probably greater than the chart indicates. The earliest timber sales on the national forests, from the standpoints of accessibility and quality of material, were naturally located in the most desirable timber. More recently, cutting has extended to more remote and poorer timber as the choicest chances were liquidated. Thus, in figure 8, the prices for sugar pine in the 1940's were for a lower quality commodity than those of 1910 to 1920, if all aspects of quality, such as terrain, distance to mill, and density of stand, are considered.

A second factor, clearly important in determining consumption, is the general level of economic activity in the nation. This may be measured by *gross national product*, a statistic which represents the total value of all goods and services produced by the economy during a year (U. S. Department of Commerce, 1951). A third consideration which has influenced stumpage prices has been the migration of the lumber industry into California. As timber supplies in other sections of the country decreased and

stumpage prices rose, an increasing proportion of both the California and the national lumber market was supplied by California. This has resulted in a general long-term rise in the price of all California stumpage (Gulick, 1951). Changes in this influence may be measured quantitatively by changes in the ratio of California lumber production to national lumber production (Steer, 1948).

Regression analysis of the data just described, for the forty-year period 1910 to 1949, shows a high degree of relationship between sugar pine stumpage consumption, and stumpage prices, the level of general economic activity, and the competitive position of California in the lumber industry.*

About 60 per cent of the variation in sugar pine consumption is associated with changes in stumpage prices, gross national product, and the general shift of lumbering toward California which has occurred during the last forty years. The remaining variability in consumption is associated with unidentified market factors. However, analysis shows that the net effect of these other sources of variability is not correlated with time. In other words, over the forty years of observation, no long-time trends were observed other than those associated with changes in price, gross national product, and shifts in the location of lumber production.

The relationship between consumption, price, and gross national product is shown in figure 9, with the effect of the competitive position of the California industry held constant.

These historical relationships appear to provide the best available tool for fore-

* The following regression equation was obtained:

$$Y = 72.47 - 16.50 X_1 + 1.078 X_2 + 21.02 X_3$$

where Y = sugar pine consumption in millions of board feet

X_1 = average stumpage price in dollars (1939) per M board feet

X_2 = gross national product in dollars (1939)

X_3 = an index of the competitive position of the California lumber industry

The adjusted coefficient of multiple correlation was 0.77. The regression coefficients are all significant at the 5 per cent level of probability. Readers unfamiliar with the procedures of statistical demand analysis will find a brief further discussion of the subject in Appendix B.

casting the demand conditions for sugar pine in the future. Data for a longer historical period would of course be highly desirable. But they simply are not obtainable. In view of the fact that some forecast of future market conditions is implicit in the nature of our problem, it is proper to base this on the best analytical tools available. If these tools are less than perfect, they are still helpful in suggesting the future possibilities. As time goes on and more experience accumulates, the basis for forecasting may be further refined within the present framework of analysis.

The mathematical relationships established for the 1910 to 1949 period between consumption, price, gross national product, and economic position of the California lumber industry will therefore be used as a basis for estimating future demand for sugar pine timber. We may project the future market by making certain assumptions about the levels of national output and the competitive position of California lumbering which will then prevail. We may anticipate that after the year 2010, the lumber industry in California will face sterner competition than

at present because, by then, its reserve of virgin timber will be practically gone (U. S. Forest Service, 1946). As has already been noted, trends in migration will probably be an offsetting factor. But on balance it seems likely that California will then produce a smaller proportion of the nation's lumber output than it does today.

At the same time we may expect an expansive influence in the form of future increases in gross national product. Population increases and, above all, the steady rise of output per man hour imply at least a three-fold increase in gross national product over the next half century (U. S. President's Materials Policy Comm., 1952). After weighing the probabilities and the influence of these factors, a conservative projection of sugar pine demand in the period 2010 to 2069 seems to be that of figure 10.

Significance of sugar pine for western pine industry

A final aspect of the values at stake in the sugar pine situation concerns whether or not important indirect economic benefits are involved. Such benefits

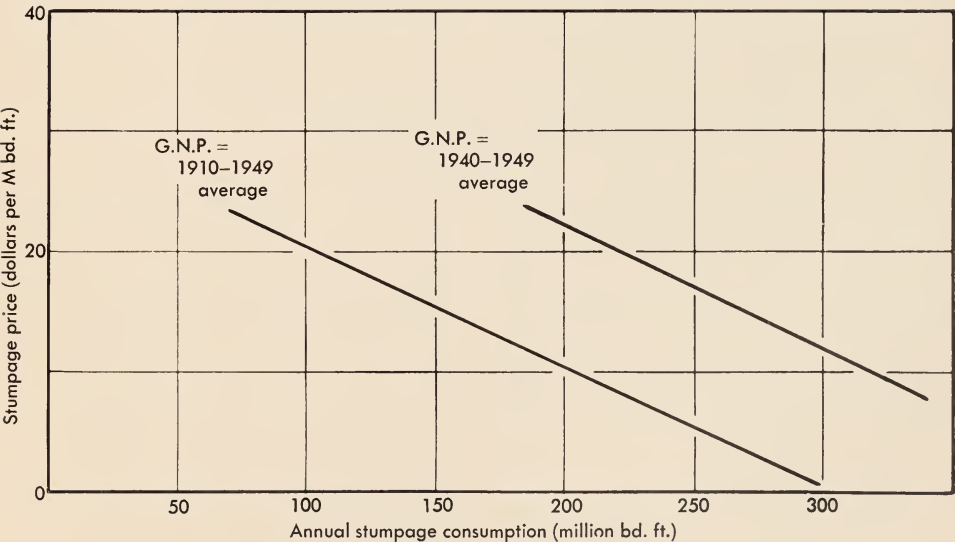


Fig. 9. Net relation between sugar pine stumpage prices and consumption, at selected levels of gross national product.

might accrue if, for example, the lumber industry of the region were largely dependent on the sugar pine resource. The industry of the western white pine region is in exactly this position (Matthews and Hutchison, 1948). Analysts have suggested that if the white pine component of production were eliminated from the sawmills of northern Idaho and western Montana, the entire industry would collapse, because its profitability depends almost entirely on white pine manufacture. But similar conditions do not appear for sugar pine.

The potential economic effects on the lumber industry of decimation of the sugar pine resource depend on two factors: 1) the relative importance to the industry of the existing scale of sugar pine utilization; and 2) the ease with which the industry could compensate for the loss of sugar pine.

In California, sugar pine comprises about 12 to 15 per cent of the output of the industry of the pine region. In local areas the proportion runs higher, amounting (in 1946) to over 25 per cent in Fresno and Tuolumne counties (May and Simontacchi, 1947). In 1946, 57 produc-

ers cut 25 per cent or more of their output in the form of sugar pine. These producers accounted for about one fourth of all pine-region output. According to data supplied by the Division of Forest Economics of the California Forest and Range Experiment Station, of the 57 firms, 16 large ones were responsible for more than 90 per cent of the output of the entire group.

Without doubt, major problems would be posed for these large sugar pine producers and for the lumber economy of those counties which cut large volumes of the species, if the supply of sugar pine were to be severely curtailed. They might well have to speed up liquidation of old growth in order to minimize mortality, with consequent reductions in the volume, quality, and value of their cut. In the longer run, the permanence of these enterprises might be endangered by loss of raw material supplies suitable for their operation. However, for most of the industry the effects would be by no means disastrous. Although there might be some temporary reduction in the size of the timber resource base, it seems unlikely that this would exceed 5 per cent in ag-

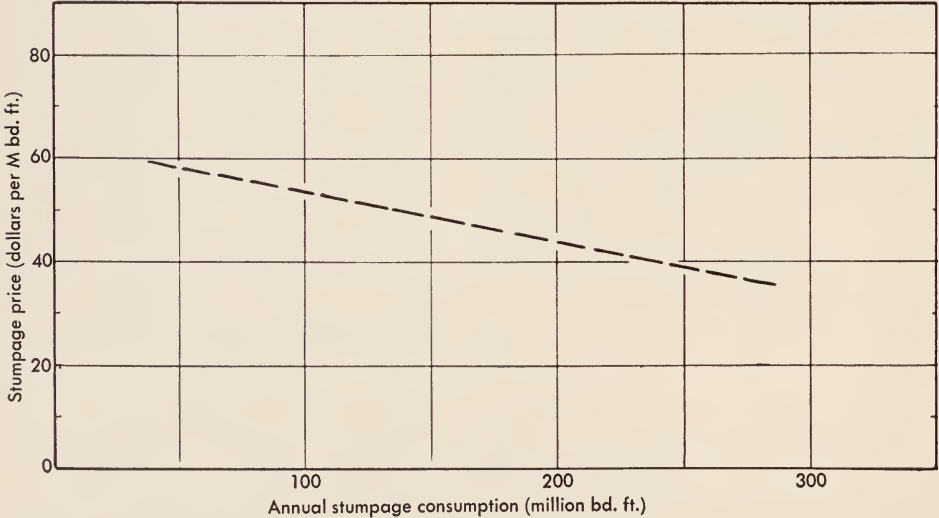


Fig. 10. Estimate of potential demand for sugar pine stumpage during the period 2010 to 2069.

gregate. Probably the industry could more than compensate for such a volume loss by closer utilization of other species.

A more serious matter from the standpoint of profit margins would be the lower average value per unit of lumber cut, which might result. Elimination of a substantial volume of premium quality material from the "mix" of lumber produced by some firms would undoubtedly have significant adverse effects on them. These should not be overemphasized, however. Even in old-growth timber, less than 40 per cent of the sugar pine cut is premium material. The rest is common grade which could be replaced by ponderosa pine commons or even by other species with little effect on gross returns and profit margins.

The indirect impact on the lumber economy, of the loss of sugar pine thus comes down to the question of how the industry might be able to adjust to the elimination of the 6 to 8 per cent of its present cut which constitutes premium grade sugar pine. Here the critical factor is one of how quickly the adjustment must be made. There is little doubt that if sugar pine resources were to be wiped out within a very few years, many firms would face serious difficulties as a result

of curtailed profit margins, losses of capitalized timber values, and the need to reorganize drastically their marketing arrangements. Those firms whose production runs heavily to sugar pine might well be unable to survive. But such a prospect seems wholly unlikely. If sugar pine is not protected from blister rust, and if the disease does wipe out the commercial stands, it will probably do so only over an extended period of years. During this period of several decades, industry would have both the opportunity and the ability to adjust itself to the changed resource situation. There would be time to salvage the capital values which would be jeopardized. Operating policies and marketing programs could be adjusted gradually and without major dislocation to more than a very few individual firms.

In view of these circumstances, there seems no reason to believe that sugar pine is indispensable to profitable operation of the lumber industry. We must conclude that the principal economic values at stake are the direct ones, derived from the growth and manufacture of a high quality commodity, even though some indirect influences would be felt throughout important segments of the industry.

COSTS OF GROWING SUGAR PINE AND PROSPECTIVE SUPPLIES

The considerations of demand, which have just been analyzed, are the first major element in the economics of the sugar pine situation. Equally important is the second of these elements—what it will cost to grow the species. If we grant that sugar pine stumpage has definite and measurable values for our economy, we still must show that these values will equal or exceed the costs of obtaining them. For if these costs are greater than the values derived from sugar pine, then it is clearly uneconomic to expend effort in producing them.

The costs of growing sugar pine vary tremendously. On good sites with heavy sugar pine stocking and low costs for blister rust control, established young sugar pine stands may be brought to maturity for an additional cost as low as \$7.50 per M board feet. But where the land is less productive, or where there is relatively little sugar pine growing stock, or where rust control is difficult, the additional costs may easily exceed \$150 per M. Accordingly, we need to know how sugar pine production costs vary—what quantities of sugar pine could be pro-

duced at various alternative levels of expenditure.

Basis of cost estimates

We are concerned with those particular costs which we will have to incur in the future especially because of sugar pine. It now seems certain that all of the commercial forest area in the sugar pine region will be protected from fire and will receive a minimum amount of general administrative care regardless of whether or not we grow sugar pine on the area. Both public agencies and the principal private land owners have followed this policy for many years. Because of the nonsugar pine values which are present there—timber other than sugar pine, watershed protection, and recreation—these policies seem certain to continue regardless of what is done about sugar pine. Thus future fire protection, general administration, and perhaps certain other costs of this kind need not be charged against sugar pine for purposes of the present analysis, because the land will receive this kind of care as part of the general forest management program to which the mixed conifer forest now seems certainly committed.

The principal special costs of sugar pine management with which we are concerned, therefore, are those for protection against blister rust and for special silvicultural measures needed to insure survival of sugar pine in optimum quantity and quality.

As the several items of cost will be incurred over a period of years, they must be placed on a comparable basis by use of customary discount procedures. Choice of the discount rate appropriate for this purpose is, of course, fraught with all of the customary difficulties of such problems. Because of the long-time period involved in investments in sugar pine young growth, the rate must be low enough to reflect realistic possibilities for earnings of any investment involving a number of decades. Also, in order to

avoid arbitrary inflation of risk allowances as a result of compounding, a *risk-free* rate seems appropriate. The risk item can then be handled as a separate factor, as discussed below. Finally, the present appraisals are of the entire sugar pine industry, and of its importance to the rest of the economy. Therefore, the economic viewpoint is that of the public at large, rather than that of the private entrepreneur. Accordingly, the average yield on long-term government bonds, as of 1950, appears to be appropriate. Further discussion of the rate of interest appropriate for use in evaluating projects where questions of the public interest predominate is presented by the United States Interbureau River Basin Committee (1950). For purposes of this study the rate has been taken as $2\frac{1}{2}$ per cent.

As discounting is to be done at a *risk-free* rate, some further allowance for risk is required. There is practically no basis in experience for appraising such risk. It may be noted, however, that the investments here envisaged will be in intensively managed enterprises with a high level of protection from all kinds of forest enemies. The risks of loss of the forest capital as a result of destructive human or biological agencies would thus appear to be no greater, and perhaps less, than those of most current forest management enterprises. Great uncertainty of future markets arises as a result of the long-time period involved. But again, the market uncertainty would seem to be less than that for most forest investments because we are dealing with a product of high intrinsic quality and wide adaptability. Moreover, some allowance for market risk has already been made through the use of generally conservative assumptions as to future levels of economic activity. In the light of these considerations a risk allowance of 25 per cent of other costs will be employed.

All prospective costs are estimated in terms of 1950 dollars in order to avoid the complications of a changing price

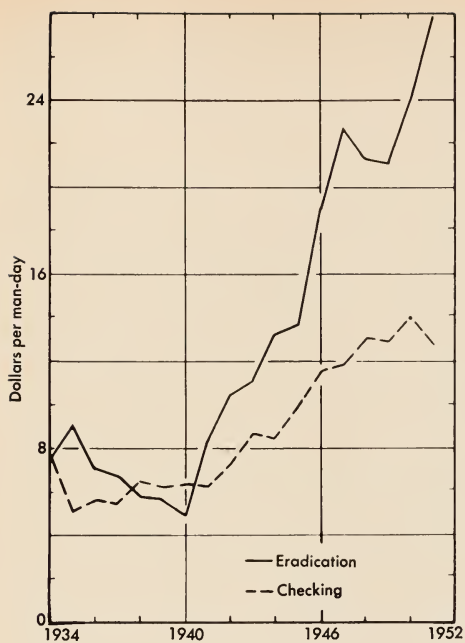


Fig. 11. Average cost of Ribes eradication and of checking on sugar pine lands. Pacific Coast Region, 1934 to 1952. Source: U. S. Office of Blister Rust Control.

level and to insure comparability with the demand estimates of figure 10.

Blister rust control. Such costs vary with the density of Ribes occurrence, the nature of the ground and vegetative cover, and the extent of disturbance to the stand by logging and similar activities. Where these factors are constant, the costs of control vary directly with the size of the area controlled and are independent of the quantity of sugar pine present. Traditionally, control has been achieved by hand eradication of Ribes bushes. As a result, money costs per acre have increased rapidly during recent years because of rising labor charges (U. S. Bur. Entomology and Plant Quarantine, 1951*b*). However, important relative economies have been realized by development of chemical methods of eradication and by replacement of wage labor (housed in government camps) by contract workers. Past trends and variability of costs are shown in figure 11.

In the light of the experience of the Office of Blister Rust Control, the basic cost rate assumed in this study is \$18.00 per man-day for field work. On this basis, eradication costs per acre can be computed for various levels of needed control effort ranging from half a man-day to five man-days per acre. (The term *five man-days per acre* means that an aggregate of five man-days of work, applied in several successive treatments of the area, will be needed to reduce the Ribes potential to the point where the species can be effectively controlled by occasional maintenance work.) The resulting rates are shown in table 6. They include the basic labor charge of \$18.00 per man-day, plus \$2.00 per man-day for supervision and \$0.25 per acre to cover costs of selecting control areas. The rates are adjusted for economies which experience shows can be achieved in contract work. They include the costs of the repeated workings of an area which are necessary in order to maintain protection. The total control effort is spread over a number of years. Hence, the cost rates shown give the present worth of all expected future control expenditures, using a 2½ per cent per year rate of discount.

Thinning. These costs must be charged against the sugar pine crop because, unless sugar pine crop trees are kept free from competition of fir and other associates, their rate of growth will be seri-

Table 6. Present Worth of Total Costs of Ribes Control, for Protection from 1950 to 2070

Eradication effort required (Man-days/acre)	Total present worth of control (Cost/acre)
0.0–1.0.....	\$ 13.00
1.1–2.0.....	27.00
2.1–3.0.....	42.00
3.1–4.0.....	59.00
4.1–6.0.....	85.00

ously impaired. Such crop tree release cuttings are needed about every twenty years until the trees attain an age of sixty years. Thereafter, sugar pine growth is better maintained than is that of its associates, and further silvicultural aid is not needed.

As a basis for our cost estimates, we assume that sugar pine crop trees will receive one release cutting now and another at the end of twenty years. Costs per acre are based on the number of crop trees which will require release and on an hourly cost rate of \$3.85 per crew of two men. As release cutting costs will vary with the size of the trees being cut, per acre costs also reflect variations in the age of stands. The release costs used are summarized in table 7.

Pruning. Pruning is required because the value differential in favor of sugar pine is based on Clear grades of lumber (see page 16). In the absence of pruning, only a small proportion of the yield from young growth stands will meet these grade requirements. Unless *quality* sugar pine is produced, the resultant product will be little better than lumber from competing species, which could be grown at substantially lower costs.

The basic cost for pruning assumes a one-man crew costing \$1.92 per hour (1950 dollars). Output of pruned trees is based on results obtained in pruning ponderosa pine in the Pacific Northwest

(Shaw and Staebler, 1950). These rates agree with the experience of California Forest and Range Experiment Station and with that of other agencies in pruning sugar pine. They cover the cost of pruning the butt log on all crop trees. Accordingly, per acre costs will vary with the number of crop trees per acre. The values used are shown in table 8.

The net effect of pruning on lumber grade recoveries cannot be forecasted with assurance because pruned sugar pine trees have not yet reached maturity. Some general indicators of the probable results are available, however. Old-growth trees 32 inches in diameter (the average size of the harvested trees here considered) yield about 25 per cent of lumber in grades better than No. 1 Common (Brundage, Krueger, and Dunning, 1933). Theoretical analysis of the knot structure of the butt log of a 32-inch tree, pruned when it was 12 inches in diameter, also indicates that 20 to 25 per cent of the yield of the entire tree will be sawable as knot-free lumber. It thus seems probable that pruning will permit production of a crop containing 25 per cent of Clear material. The average grade recovery is then likely to be somewhat below that of the virgin stands currently being logged (see page 16), but far above that of unpruned stands. Whether or not this high-grade material will be fully reflected in stumpage prices received by the owner

**Table 7. Present Worth of Total Cost of Release Cutting
(Two cuttings, twenty years apart, all sites)**

Present age of stand (Years)	Number of crop trees and costs*/acre				
	14.0 or more	10.0-13.9	6.0-9.9	2.0-5.9	0.0-1.9
1-20.....	\$ 10.10	\$ 4.70	\$ 3.90	\$ 2.20	\$ 1.00
21-40.....	11.00	5.40	3.90	2.20	1.00
41-60.....	13.50	6.50	3.90	2.20	1.00
61 +.....	14.40	7.10	3.90	2.20	1.00

* Assumes each release cut will remove one tree of equivalent size for each crop tree on the area.

Table 8. Present Worth of Pruning Costs

	Density of sugar pine stocking and costs/acre				
	Heavy	3	2	1	0
Pruning cost/acre*	\$12.60	\$ 5.40	\$ 3.60	\$ 1.80	0
Present worth of pruning cost	11.10	4.80	3.20	1.40	0

* Assumes cost of \$0.45 per tree for each crop tree.

will depend on the extent to which satisfactory means are developed for identifying pruned growing stock when it has reached maturity.

Road and other capital developments. These are included as special costs of growing sugar pine because the necessary intensity of management is substantially greater than that now characteristic of general forestry practice in the pine region. In order to permit crop-tree release, pruning, and harvest cuttings at frequent intervals, more roads and operating facilities will be required. Hence, a fixed capital charge of \$8.80 per acre is included in costs to cover such items. The cost estimate is based on the additional road development required for representative sample sugar pine management areas.

Replacement by other species. A final aspect of cost concerns the other values that must be foregone in order to grow sugar pine on the areas in question. If sugar pine were not managed, would it not be replaced by other competing trees which would yield substantial values? Therefore, shouldn't these values which we forego in our effort to produce sugar pine be considered as a kind of cost of sugar pine management? In theory this view is correct. Moreover, where sugar pine is likely to be replaced by high-value ponderosa pine, it is likely to be practically important. However, preliminary but suggestive studies of this question of replacement indicate that in most instances sugar pine crop trees will be supplanted by fir, or incense cedar,

with relatively low stumpage values, or by brush (U. S. Forest Service, 1952). On sample areas, less than half of the sugar pines were subject to replacement. When allowance is made both for the fractional rate of replacement and for the lower value of the resulting yields, the costs, because of this, appear to be of the order of \$3.00 to \$4.00 per M board feet of sugar pine. Considerable additional detailed study would be necessary to estimate the specific effects of replacement satisfactorily. For the present study, a uniform cost rate of \$3.50 per M board feet of yield has been included because of the replacement factor.

Potential yields per acre

The items of cost which we have just enumerated must be paid for by the increased yields which result from sugar pine management. This increase in yield per acre depends in part on the number and rate of growth of sugar pine crop trees and in part on the extent to which their growth and survival are increased by management.

Yield estimates for stands protected from blister rust are based on: 1) the present number and the diameter of sugar pine crop trees per acre; and 2) the rates of growth of dominant sugar pines of different diameters as observed on cut-over areas. The growth rate data (furnished by the Division of Forest Management, California Forest and Range Experiment Station) are shown in figure 12. In order to be consistent with other assumptions of this study, it is assumed

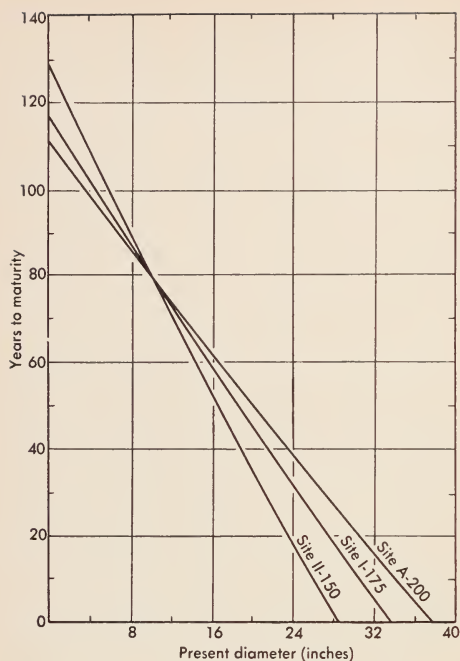


Fig. 12. Number of years required for sugar pine crop-trees to reach maturity in managed young-growth mixed conifer stands. (Based on growth of dominant stems on cutover areas during the first twenty-five years after logging.)

that crop trees will be harvested when their current annual growth per cent declines to $2\frac{1}{2}$ per cent. As current annual growth per cent varies with site quality, the size of a *mature* crop tree will vary with Site class as follows:

Site class	Diameter of mature tree (inches d.b.h.)	Volume of mature tree (bd ft)
A-200	38	2780
I-175	34	1750
II-150	30	1050
III-125	26	700

(No analysis has been made of growth on Sites IV and V because such areas obviously are not ordinarily sufficiently productive to produce sugar pine economically under management.)

Using the premises just outlined, yields may be computed for any young-growth stand whose present stocking and Site class have been observed. For ex-

ample, sugar pine reconnaissance data show that the average stocking on Site I-175 land cut within the last twenty years and moderately well stocked with sugar pine (10.0 to 13.9 crop trees per acre) is as follows:

Present d.b.h. (inches)	No. of crop trees/acre
less than 2	1.56
2	2.90
4	1.50
6	1.18
8	0.94
10	0.92
12	0.94
14	0.73
16	0.71
18	0.62
20	0.35
22	0.28
24	0.26
26 or greater	0.35

Using figure 12 to determine when trees of given present diameter will reach maturity (34 inches d.b.h.), the number of crop trees and volume of yield during successive twenty-year cutting cycles may be determined as shown in the middle column of the tabulation below.

Similar calculations may be used to forecast the yield for stands of different Site-class and different present stocking.

The yield estimates just described assumed that the sugar pines in the stand

Cutting cycle	Yield per acre	
	With sugar pine management	Without sugar pine management
	M board feet	
1950-1969.....	0.3	0.2
1970-1989.....	0.8	0.5
1990-2009.....	2.2	1.4
2010-2029.....	4.2	1.0
2030-2049.....	5.3	1.3
2050-2069.....	10.4	1.4
Total from established growing stock.....	23.2	12.8

would be protected from blister rust and managed to maintain maximum growth. Yields in the absence of such special management measures may also be estimated. Starting with the present crop-tree stand table, the rust survival rates of figure 3 (medium hazard) are applied, diameter class by diameter class, to obtain an estimate of the number of sugar pines which will mature in the face of the rust. The growth of these surviving trees is now projected at rates appropriate for stands in which sugar pine will not receive preferential thinning treatment (Dunning, 1949). The results, cumulated to provide estimates of the yield per acre, are shown in the last column of the preceding table.

Cost per M of sugar pine yield

We may now estimate the additional costs of growing sugar pine, under varying circumstances, by combining forecasted yields with the estimates of cost per acre which have previously been discussed. For example, on land cut twenty-one to forty years ago, which is moderately well stocked with sugar pine crop trees (10 to 14 trees per acre) and where blister rust control effort will average 1.5 man-days per acre, reference to tables 6, 7, 8, and the related text shows that the present worth of the additional costs of sugar pine management measures is estimated as follows:

	<i>Per acre</i>
Blister rust control.....	\$27.00
Release cuttings	5.40
Pruning costs	4.80
Allowance for replacement....	3.50
Roads and other capital improvements	8.80
Total extra cost of management	\$49.50

This represents the value, now, of all the expenditures which will have to be made in the future in order to bring through to maturity the crop trees now existing in this stand. Costs incurred at future dates have been discounted to present worth at the rate of 2½ per cent per year. All cost rates are based on experience

with each of the indicated types of activity conducted as a separate operation. An integrated program of management work could conceivably result in somewhat lower levels of cost.

These costs may now be expressed in terms of the additional yield obtained, that is, costs per M board feet of additional sugar pine harvested. As an illustration, let us assume that the stand in question is on Site-class I-175. From the preceding section we learn that the *increase* in yield resulting from blister rust control and stand improvement measures is as follows:

<i>Cutting cycle</i>	<i>Increased yield (M bd ft/acre)</i>
1950-1969	nil
1970-1989	0.9
1990-2009	0.8
2010-2029	3.1
2030-2049	6.1
2050-2069	6.9

These yields represent the joint product of all of the management efforts begun now and continued over the years. In other words, the cost per M of all these yields is the same, regardless of the cutting cycle in which the yield is realized. Thus, if this cost per M be designated as X, the present value of the cost per acre of the yield in a single cutting cycle is equal to X times the yield during that cycle, discounted (at 2½ per cent interest) by the number of years between now and the midpoint of the cycle. Thus the present value of the costs per acre for the third cutting-cycle may be written:

$$\frac{0.8 X}{(1.025)^{50}}$$

Similar terms may be calculated for the present worth of each of the other cutting cycles. The sum of these terms is equal to the present worth of additional sugar pine management costs for one acre. For the stand in question this was already estimated at \$49.50. This relationship provides us with the necessary algebraic equation to estimate the aver-

age additional cost per M of sugar pine yield for the stand in question. The expression is:

$$\frac{0.0 X}{(1.025)^{10}} + \frac{0.9 X}{(1.025)^{30}} + \frac{0.8 X}{(1.025)^{50}} + \frac{3.1 X}{(1.025)^{70}} + \frac{6.1 X}{(1.025)^{90}} + \frac{6.9 X}{(1.025)^{110}} = \$49.50$$

Solution of this expression gives a cost estimate of \$20.34 per M of additional sugar pine produced. This represents the value, now, of all the expenditures which will have to be made on stands of this kind in order to bring all of the crop trees through to maturity. Similar calculations have been carried out for other representative sites, conditions of stocking, and levels of management cost.

The range of costs under different timber growing conditions is very great, depending on site quality, difficulty of rust control, density of stocking, and related factors. On Site A-200, with moder-

ate sugar pine stocking (10.0 to 13.9 crop trees per acre) low control costs, and medium rust hazard, sugar pine yields may be increased by 21 M board feet per acre at an additional cost of \$10.00 to \$13.00 per M. On the other hand, on Site II-150 land, with light stocking (two to six trees per acre), and heavy control costs (3.5 man-days per acre), the costs may exceed \$200 per M to get an additional yield of 900 board feet per acre. The relationship between additional cost per M and site quality and present stocking is shown in figure 13 for areas where rust-control costs are moderate.

Potential sugar pine supplies from young-growth areas

Having recognized that costs vary so widely with stand conditions, we need now to estimate how much sugar pine could be produced at the various possible levels of cost. To do this, we need to know, first, the site, stocking, and rust-control characteristics of the available cutover land. Estimates of these characteristics have accordingly been prepared, based on reconnaissance data obtained by the Office of Blister Rust Control and the Forest Service.

Physical productivity. A number of classifications of land, representing the different sites, densities, and ages of young-growth sugar pine were first set up. All young-growth sugar pine land of Site III-125 or better quality was then classified into one of eighty site-density-age classes. The estimated area of land in each class is shown in table 9. Field samples of each of these eighty classes were measured in order to get an estimate of the number and size of sugar pine crop trees in each class. Crop-tree stand tables were then prepared for each of the 80 classes.

Using these stand tables, the yield per acre from each class was next calculated, assuming no special measures to favor sugar pine. The methods of forecasting yield per acre were those described above.

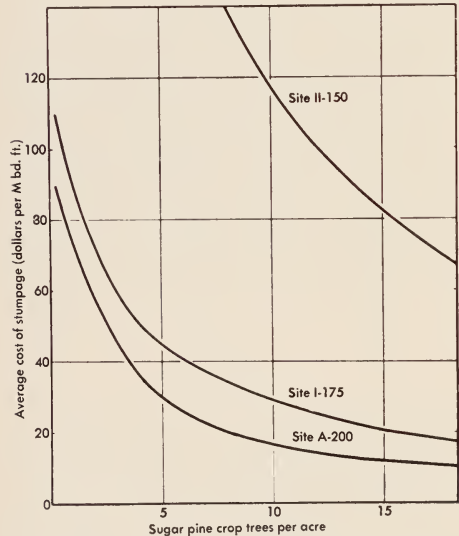


Fig. 13. Variation in estimated cost per M board feet of additional sugar pine produced, by site-class and present degree of stocking. (Rust control requiring 1.5 man-days per acre; medium rust hazard.)

**Table 9. Estimated Area of Cutover Sugar Pine Land in California
and Oregon by Density of Sugar Pine Stocking
and by Date of Cutting
(Area in thousands of acres)**

Sugar pine crop trees per acre	Date of cutting				Total area
	Pre-1891	1891 to 1910	1911 to 1930	1931 to 1950	
Site A-200					
14 or more	0	0.1	0.6	3.2	3.8
10.0-13.9	0	*	0.5	1.9	2.4
6.0- 9.9	0	0.1	1.0	2.5	3.6
2.0- 5.9	0	0.1	1.3	4.7	6.1
1.9 or less	0	0.5	5.2	13.6	19.3
Total	0	0.8	8.5	25.9	35.2
Site I-175					
14 or more	0.4	5.8	35.3	28.7	70.2
10.0-13.9	0.2	2.3	14.6	15.9	32.9
6.0- 9.9	0.3	3.7	22.9	26.5	53.3
2.0- 5.9	0.3	3.3	17.8	38.2	59.6
1.9 or less	0.8	8.5	77.1	117.9	204.3
Total	1.9	23.6	167.8	227.2	420.5
Site II-150					
14 or more	*	0.1	12.3	26.8	39.3
10.0-13.9	0	0.1	7.6	21.4	29.1
6.0- 9.9	0.1	0.1	9.5	33.4	43.1
2.0- 5.9	*	0.3	11.3	62.8	74.4
1.9 or less	0.3	1.3	63.5	134.2	199.3
Total	0.4	2.0	104.2	278.7	385.2
Site III-125					
14 or more	0	2.0	5.2	7.8	15.0
10.0-13.9	0	1.5	3.3	7.6	12.4
6.0- 9.9	0	2.5	8.5	12.0	23.0
2.0- 5.9	0	3.5	9.6	21.3	34.5
1.9 or less	0	9.7	32.7	49.7	92.1
Total	0	19.2	59.3	98.5	177.0
All sites					
All densities	2.3	45.5	339.9	630.3	1,017.9

* Between 0 and 50 acres.

Note: Totals may not add because of rounding.

These per acre yield estimates were then combined with the acreage figures of table 9 to obtain an estimate of the sugar pine yield which would be obtained if no special sugar pine management were undertaken—that is, the supply that would be available at \$0.00 per M of additional cost. The estimate indicates an average annual yield of 22.4 million board feet per year during the period 2010 to 2069.

Cost of management. Next, the acreage data of table 9 were further subdivided on the basis of variations in the level of rust-control cost. For example, reconnaissance data indicated that of the 35,000 acres of sugar pine land in the “Site I—14 or more crop trees—1911 to 1930 cutting” element of table 9, 15,500 acres were land where control costs were estimated at from zero to one man-day per acre; 5,800 acres were where control would cost one to two man-days per acre; 10,700 acres would cost two to three man-days per acre; and 3,300 acres would cost more than three man-days per acre. As a result of this further classification, estimates were obtained of the area in

each of 280 site-stocking-age-control cost classes.

Similarly, the increase in yield per acre resulting from special management measures was calculated for each class by using the stand tables and the yield projection methods already described. These increases in yields per acre then provided the basis for estimating the additional cost per M on each of the 280 classes of land, using methods given on page 31.

Finally, the 280 classes of land were arrayed in order of increasing additional cost per M, as illustrated in table 10.

Potential supply from young growth. Inspection of this table will help to clarify the relationship between sugar pine supply and the additional cost per M needed to produce that supply. As already noted, an average annual yield (over the period 2010 to 2069) estimated at 22.4 million board feet of sugar pine per year will be obtained with no special management effort whatsoever. If we are willing to spend not more than \$5.00 per M for special measures to increase yield, the increase in supply will be nil because there is no young-growth

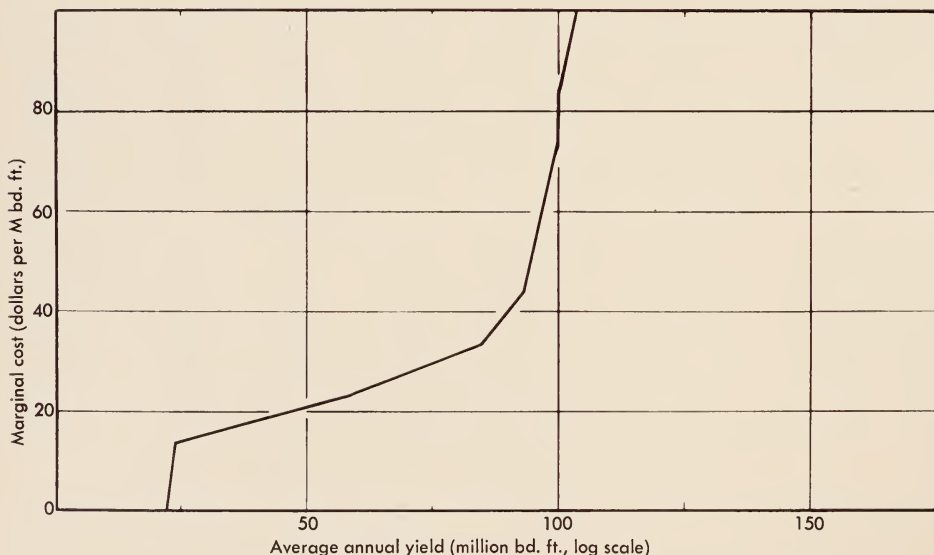


Fig. 14. Potential sugar pine yields from existing cutover lands, at alternative levels of maximum additional (marginal) cost.

Table 10. Portion of Tabulated Array Showing Supplies of Sugar Pine Obtainable from Cutover Land as Management Is Extended to Areas of Increasing Costs per M

Class of cutover land	Additional cost per M of added yield	Additional area (M acres)	Average annual yield (MM bd ft)	
			Additional	Cumulative total
All land without special management	\$ 0.00	....	....	22.4
A-31-3-0	7.05	0.2	0.10	....
A-31-4-0	9.62	0.2	0.30	22.8
A-51-4-2	10.16	0.1	0.06	....
A-31-4-2	10.56	0.1	0.16	....
A-11-4-0	10.69	2.1	2.71	....
A-11-4-1	11.29	0.4	0.46	....
A-31-2-0	13.23	0.6	0.19	....
A-31-4-2	13.31	0.2	0.22	....
A-11-3-0	13.45	1.1	0.48	....
A-31-3-1	14.03	0.1	0.05	....
A-11-4-2	14.28	0.7	0.91	....
I-30-4-0	14.31	15.5	10.83	....
I-50-4-0*	14.86	4.4	2.26	41.1

* Remainder of table not reproduced.

area available on which the costs will be this low. If we are willing to spend as much as \$10 per M, yields can be increased a little, but the area of high site, well stocked (and hence low cost) land is so small that the aggregate increase in supply is only about 400 M board feet per year. However, if we are willing to spend as much as \$15 per M for additional sugar pine, supplies can be almost doubled, because at this level of maximum additional cost a relatively large acreage of land is available for management and it will produce relatively high yields per acre.

The entire array, of which table 10 presents only the first few items, is represented by the curve of figure 14. The curve is obtained by plotting cumulative sugar pine yields (column 5 of table 10) against maximum additional cost per M (column 2 of table 10). It represents what we may call the *potential* supply

curve for sugar pine from existing cutovers. It shows the estimated amounts of sugar pine that could be supplied at any desired level of maximum additional cost.

In passing, it should be noted that the curve does *not* tell us the average cost per M of the several levels of output. This average cost will be considerably below the maximum cost shown in the figure, and is not relevant to the problem we are trying to solve.

One feature of the cost curve of figure 14 merits comment. Potential increases in supply become relatively small after we go above the \$60 per M level of cost. This is so because, in this portion of the curve, a principal reason for increasing cost is a low rate of sugar pine stocking. Obviously, if the stocking is low, the increased yield obtained by management will inevitably be small, even if the acreage of land which can be brought into production at this cost level is large.

Total potential supply

The last several sections have focussed attention on the cost of growing sugar pine on lands which are now cutover. Because the growing stock on these lands is of widely varying age, the yields from these areas will be spread over a period extending from the present to the year 2090. But the great bulk of the yield will be concentrated in the period 2010 to 2070. Thus, relatively little sugar pine young growth will be ripe for cutting until about sixty years hence.

Old growth. In the meantime, we must depend heavily on the remaining stands of old growth to meet our needs. In 1951 there was an estimated 18.8 billion board feet log scale of sugar pine remaining in commercial old-growth stands. From 1940 to 1948 the average rate of cut of sugar pine was about 320 million board feet per year. At this rate of use, the old-growth supply represents a little less than sixty years' cut. In other words, if all sugar pine cutting were concentrated in old-growth stands, those stands would last until 2010.

However, the future supply outlook is complicated by several factors. On the one hand, much of the old-growth sugar pine is in ownerships which are committed to sustained forest production. On such areas, the liquidation of the old-growth stems is likely to be spread over a longer period of time, and, as growth is built up, the yield from old growth may exceed the present estimates of volume. On the other hand, our analysis of demand suggests pressures for further expansion of the cut, which may well result in consumption above the 320 million foot annual level. Some expansion can be achieved by reductions in waste—in effect, increasing the available supply. But there are sharp limits to this sort of economy. Finally, existing data on past sugar pine production probably understate the actual level of cut because most mills do not sort out common-grade sugar pine lumber. Hence, at least some of it is

probably not reported as sugar pine production.

Although the outlook is thus obscured, it seems highly probable that by the end of another half century the sugar pine economy will begin to rely very heavily on the yields from lands which are now cutover.

Other supply elements. But total supply will not be confined to material obtained from these presently cutover areas. Residual stands will be left on such old-growth areas as are cut during the next several decades. These residual volumes will also contribute to the supply of sugar pine available after 2010. In other words, from 2010 to 2070 total sugar pine supply will exceed the annual yields of figure 14 by whatever amount is then available in reserve growth on presently uncut areas.

At first glance it might appear that possibilities of establishing sugar pine plantations, now or in the future, should also be considered in relation to the current discussion of supply. However, this is not the case. Any plantations set out henceforth will not mature until after the end of the 120-year supply period under discussion. For this reason, analysis of planting possibilities falls outside the scope of the present work.

Total supply. Figure 15 suggests what this total sugar pine stumpage supply may look like. The estimates are derived by adding to the previous estimates of supply from cutover land (see fig. 14) the potential reserve volume on lands now uncut, which would mature during the market period in question. The estimates are based on the assumption that existing old-growth stands will be cut at a rate equal to that of the last decade, and that the pattern of site, stocking, and cost of control on future cutovers will be similar to that of those which now exist.

We should note carefully that figure 15 does not attempt to show what future sugar pine supplies *will be*. Rather it attempts to estimate what those supplies

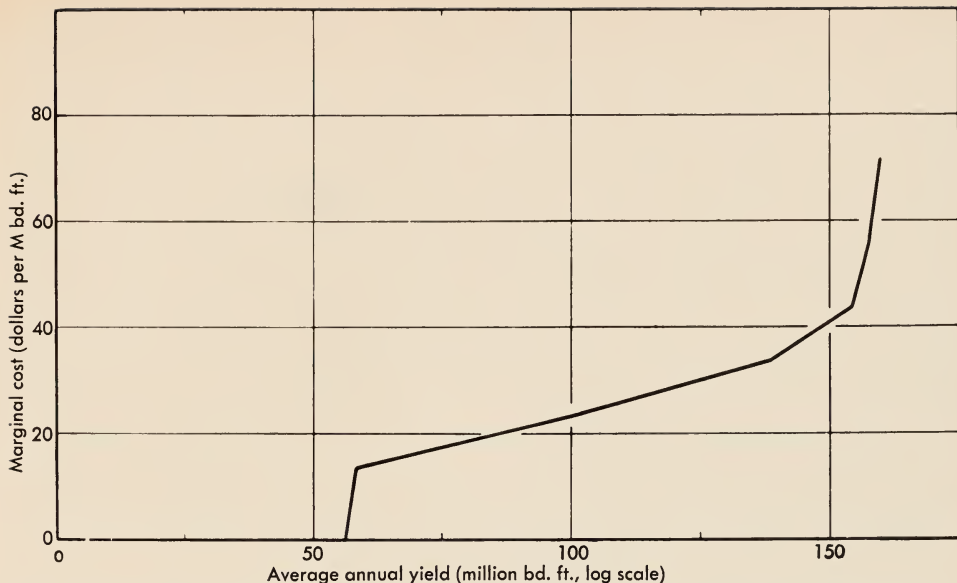


Fig. 15. Potential total supply of sugar pine—average annual supply for the years 2010 to 2070.

would be if we put into effect special measures for sugar pine management by extending those measures first to lands of lowest cost, achieving expansions in our supply by including successively higher cost areas.

Timing. For simplicity, figure 15 has been drawn in terms of average annual yield over a sixty-year period. Actually, because of present size distribution of sugar pine growing stock, it will be quite difficult to realize the yields on an equal

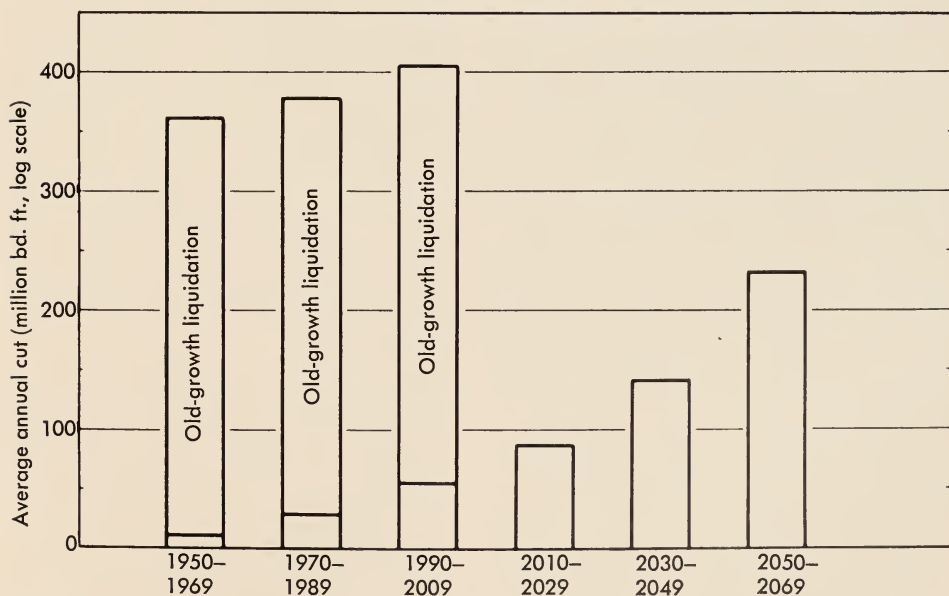


Fig. 16. Average annual mature sugar pine supply during the next 120 years, by twenty-year periods, if sugar pine management is applied to all areas where costs are less than \$50/M board feet of yield.

annual basis. Much more timber will mature in the latter part of the sixty-year interval than in the early part of it. The situation is depicted in figure 16. The bulk of the existing cutovers has been logged during the last twenty years. As a result, a disproportionate share of the growing stock is in the zero- to twenty-year age class which will not mature for a century. A comparably small proportion is in the forty- to sixty-year age class which will mature between 2010 and 2029. As a result, the sugar pine supply

situation will probably be considerably tighter in the two decades following the year 2010 than at any other time in the foreseeable future. However, the situation will not be so bad as figure 16 suggests. Forest management is a flexible process and by deferring cutting in some of the old-growth stands and by some "premature" use of the younger second growth, it should be possible to ease materially the short supply in the critical 2010 to 2029 period. This flexibility justifies use of the longer term average field.

AN ECONOMIC PRODUCTION GOAL FOR SUGAR PINE

The estimates of potential sugar pine supply and demand made in the preceding section were designed to help define an economic production goal which could serve as the broad objective of sugar pine management. Such a goal is needed as a basis for evaluating the extensive programs of state and federal action which are aimed at sugar pine production. Are these programs so large or so expensive that they involve a waste of public funds which could better be devoted to some other use? Or are they too small to insure adequate protection of resources which could contribute to the future economic well-being of the American economy? In order to answer these and related questions, we must have in mind some bench mark showing what levels of production of sugar pine timber are consistent with long-term economic balance between its supply and demand. This bench mark is here referred to as the goal in the production of sugar pine timber. A more thorough discussion of the theory of such goals is given by Vaux and Zivnuska (1952).

Growth goal. Economic criteria suggest that future production should be increased to the point where the additional cost of the last increment of sugar pine output is just equalled by the returns from its sale. The demand curve of figure 10 can be interpreted as an estimate of the average sale value of sugar pine

stumpage at various alternative levels of output. The potential supply curve of figure 15 shows the additional cost of producing the last increment of output (marginal cost) at various levels of production. When the two curves are superimposed, as in figure 17, their intersection indicates the theoretical answer to our present question.

From the figure we note that an average annual yield of 155 million board feet of sugar pine can be produced at a marginal cost of \$50 per M—that is, by placing under sugar pine management all land which can grow sugar pine at special costs of \$50 per M or less. At the same time, we see that the anticipated price of sugar pine stumpage, with consumption at 155 million board feet per year, is also about \$50 per M. Hence, we conclude that an average yield of 155 million board feet per year during the period 2010 to 2069 represents the theoretical optimum level of sugar pine growth.

If more than this volume were produced, owners would have to place under management land with such poor sugar pine stocking, or such high levels of rust-control cost that the unit cost of producing this additional yield is estimated to exceed its anticipated value. On the other hand, if less than 155 million board feet were produced, owners would be allowing some potential sugar pine yields to be

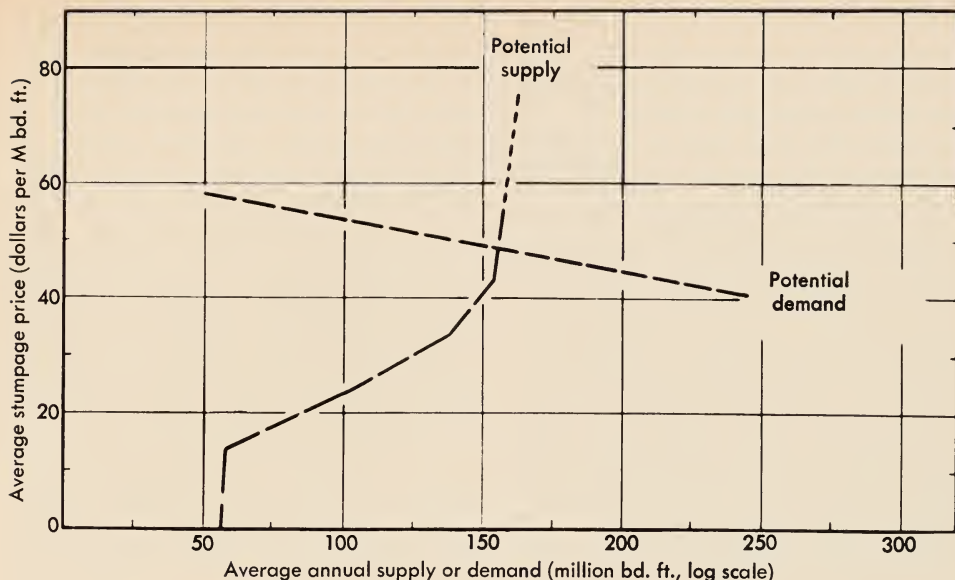


Fig. 17. Potential supply-demand situation for sugar pine stumpage: years 2010 to 2069.
(Prices in 1950 dollars.)

lost to disease or other enemies, which could have been preserved at a cost estimated at less than the prospective returns.

Average cost. Although it would cost \$50 per M to grow the last few million feet in a 155 million board foot annual sugar pine budget, the average costs for the entire volume would be far less, perhaps about \$25 per M. A large percentage of the crop would come from lower-cost land where productivity is high. The margin between this average cost and the potential \$50 per M return represents a kind of rent and is a measure of the economic value of existing sugar pine growing stock. At the time of harvest this margin would provide funds, over and above those needed to cover the cost of the prospective management program, which could be used to help bear the general cost of land administration, to write off past investments in blister rust control, and to return a profit to land owners. In other words, a sugar pine management program of the scale suggested does not result in a mere trading of present dollars for future dollars, plus

interest. Rather, it represents that scale of use of our sugar pine resource which would result in the maximum possible net economic return to the economy as a whole, if we are willing to grant the premises on which the estimates of supply and demand are built.

Goal is tentative. This answer to the question of how much sugar pine we ought to grow is, of course, a preliminary and tentative one. The nature of the case makes it so. Much of the data underlying the supply-demand analysis are based on scanty sampling or, at times, merely informed judgment. It appears to be the best information now available, but it can and should be improved over the years, particularly as our concepts of what we need most to know about the sugar pine problem become more clearly focussed.

A further reason for regarding our answer as tentative lies in the fact that the method of analysis we have used represents a rather drastic oversimplification. Like any problem in economic development, the sugar pine problem is extremely complex. The answer is influ-

enced by a tremendous number of physical and economic factors. Moreover, some of these influences are either obscure or can be forecasted only with questionable accuracy. The only way we can handle problems of this sort is to simplify them—to select for analysis those factors which seem to be the most important ones and to ignore deliberately many other influences which undoubtedly exist.

As a result of this simplification the present analysis does not consider a number of things which may ultimately prove important. For example, no attention has been paid to differences in the accessibility of sugar pine land and the effect of this on costs; the very important matter of the interdependence of sugar pine supply and demand between differ-

ent periods of time has been noted but largely brushed aside; and we have made no analysis of the effects on costs of variation in the type and intensity of sugar pine management. To have considered these things would have required kinds and quantities of data which simply are not available at the present time. Moreover, the intricacy of the resulting analysis would have been compounded. In the future much more careful attention and study must be given to these influences, and the current results must be used with full recognition of these inherent limitations. But, we may still regard these results as helpful and suggestive in the present stage of development of the sugar pine situation, provided we keep their limitations clearly in mind.

SELECTING THE MOST ECONOMICAL AREAS FOR SUGAR PINE PRODUCTION

To meet a production goal of 155 million board feet of sugar pine per year will probably require the specialized management of at least 650,000 acres of the most productive available sugar pine land. As there is several times this acreage within the sugar pine region, careful selection of areas for management will be necessary to insure the production of supplies at the lowest possible cost. The analysis which has already been made can be of considerable help in guiding this choice of the most desirable areas for growing sugar pine.

Economic criteria

Cost the basis of choice. From the standpoint of the sugar pine economy as a whole, it would be desirable if all of the most productive areas were placed under management for sugar pine, regardless of their present ownership. They represent the most economical areas for sugar pine production. If highly productive land is not managed, because of ownership characteristics, the 155 million foot goal could be achieved only by

putting under management additional land which is less productive and, hence, more costly to the economy as a whole. Accordingly, the basis for selecting sugar pine management areas should be the economic productivity of the land, without reference to ownership considerations.

Up to this point our analysis has shown that to produce an average annual yield of 155 million board feet will require special management measures on all land where the additional costs of such management are \$50 per M or less. Hence, this \$50 per M cost figure provides the basic economic criterion which should govern the choice of management areas.

Examination of the cost data underlying the supply curve of figure 17 shows that, by managing all land with a cost of \$50 per M or less, we will utilize about 230,000 acres of cutovers and 400,000 acres of currently uncut areas.

Area to be managed. The yield obtained from existing cutovers will then average about 95 million board feet per year during the 2010 to 2069 period. The

230,000 acres will include virtually all Site A-200 sugar pine land which supports more than two crop trees per acre—about 15,000 acres in total. Some 183,000 acres of Site I-175 land will be included. This is about 43 per cent of the Site I cutovers. It includes virtually all of the Site I land which now has ten or more sugar pine crop trees per acre, plus some areas where lighter stocking is offset by low blister-rust-control costs. Only about 32,000 acres of land of Site II-150 quality would be included, representing that portion of the area with a favorable combination of heavy sugar pine stocking and low control costs.

The character of the old-growth acreage needed to meet the 155 million foot goal cannot be described so readily, because much depends on what happens to sugar pine stocking at the time the old growth areas are logged.

Rating cutover land for sugar pine management

In order to apply the general criteria just suggested, it is necessary to have some scheme, adapted to field use, for evaluating sugar pine areas. Such a scheme may be developed on the basis of the estimates of cost already described.

Let us assume that we wish to distinguish, in the field, between those stands which will more than recover the future costs of sugar pine management and those which will not earn enough to cover such costs. Let us also assume that returns will be based on the \$50 per M potential stumpage price previously suggested as the probable result of 155 million board foot annual output.

Number of trees in marginal stands. The typical sugar pine stand consists of trees of a considerable range of sizes, and the economic value of a single tree will depend in a very complex fashion on its present size. If our rating scheme is to recognize this, we need separate numerical ratings for trees of each size. To obtain these we proceed as fol-

lows. For a given tract of land of known site quality, degree of rust hazard, and level of blister-rust-control cost, we compute the number of sugar pine crop trees of specified present diameter which we would have to have on each acre if the increase in returns from sugar pine management is merely to cover the costs of such management. The needed arithmetic expression is:

$$n = \frac{R + I + A}{\frac{S(Y - Y^1)}{(1 + i)^t} - P} \quad (1)$$

where n = the required number of crop trees per acre

R = present worth of expected blister rust control costs per acre

I = present worth of expected road and other improvement costs per acre

A = allowance for replacement by other species

S = expected stumpage price (per M bd ft) at time of yield

Y = expected yield (in M bd ft) per crop tree, with special management measures

Y^1 = expected yield (in M bd ft) per crop tree, without special management measures

P = present worth of pruning, crop tree release, and other stand improvement measures, on a per tree basis

i = rate of interest

t = number of years until crop trees reach harvest size

All of the terms on the right side of this expression may be evaluated on the basis of the cost and return estimates already discussed. Stumpage value (S), stand improvement costs (P) and the length of time until trees are harvested (t) will all vary with the present size of crop trees. Hence, different values of n will be obtained for each present diameter class.

By an identical procedure, the marginal number of crop trees may be determined for other site qualities (involving changes in Y and t), and for other conditions of control cost (involving changes in R). When these values have been found for the relevant magnitudes and ranges of diameter and cost variables, we may calculate the percentage of the marginal stand contributed by *one* tree of given diameter. (A marginal stand is defined as one where the expected return from the additional sugar pine produced by special management measures is just equal to the additional costs of those measures.)

Illustration of rating. As an example, for an area of Site I-175 with medium rust hazard and a level of control cost of two to three man-days per acre, solution of equation (1) shows that a stand of 11.3 eight-inch crop trees per acre would just recover the costs of management. Thus, one eight-inch crop tree contributes $\frac{100}{11.3}$, or 8.85 per cent, of the growing stock needed for a marginal stand.

Similar ratings may be calculated for other tree diameters and cost and return conditions. A sample rating table based on such calculations appears in Appendix A.

To determine whether or not a given stand is above the margin for sugar pine production at the \$50 level of anticipated price, we first sample the stand in the field to determine the average number and present size of sugar pine crop trees on the area. This might result in a tally sheet similar to that in the first two columns of table 11. At the same time, we estimate in the field the site quality and the probable level of control cost for the stand (U. S. Bur. Entomology and Plant Quarantine, 1951a). For the sample we

may next calculate the average number of crop trees per acre as in column 3 of table 11. Using the rating table of Appendix A for the indicated site and level of control cost we then enter in column 4 the appropriate rating per tree for each diameter class. The product of each of these ratings by the number of trees in that diameter class gives us a set of elements which may be added to get a total rating for the entire stand. If the sum exceeds 100 per cent, the stand may be expected to produce yields sufficient to cover the costs of future sugar pine management. If the rating is less than 100 per cent, the stand is probably submarginal for production at a \$50 price level. The rating of 100.3 in the illustration of table 11 indicates that the stand in question is just at the margin of economic management.

Use of ratings. The method of rating sugar pine stands just outlined considers the *major* factors which apparently influence the problem. But as has already been noted, many factors have been ignored. For this reason the ratings are to be considered as guides. They cannot be applied arbitrarily without the exercise of careful judgment. For example, if the stand of table 11 were known to be in a very inaccessible location, it might well be excluded from management even though rated at better than 100 per cent. Similarly, a stand rating only 95 but in a favorable location, surrounded by an extensive area of managed land, might well be included in the management program despite the nominally unfavorable rating.

Rating old-growth stands*

Selection of old-growth areas for sugar pine management is complicated by a number of factors not encountered on young-growth areas (U. S. Forest Serv-

* The concepts discussed in this section originated with personnel of the U. S. Forest Service and Office of Blister Rust Control. See U. S. Forest Service letter to U. S. Office of Blister Rust Control, S-PLANS, Timber Survey (Sugar Pine Management), dated March 27, 1952, with attached draft memorandum by W. R. Howden.

Table 11. Evaluation of a Sample Sugar Pine Stand Using Field Tally of Crop Trees on the Area* and Crop-tree Ratings of Appendix A

Tree d.b.h. (inches) (1)	Number of crop trees (2)	Crop trees per acre (3)	Rating per tree (4)	Total rating (5)
less than 2.....	18	1.12	4.4	4.9
2.....	18	1.12	5.4	6.1
4.....	23	1.44	6.4	9.2
6.....	24	1.50	8.0	12.0
8.....	23	1.44	8.9	12.8
10.....	22	1.38	10.9	15.0
12.....	16	1.00	13.0	13.0
14.....	8	.50	14.8	7.4
16.....	8	.50	16.5	8.2
18.....	4	.25	8.7	2.2
20.....	3	.19	10.3	2.0
22.....	4	.25	11.4	2.9
24.....	3	.19	12.5	2.4
26.....	1	.06	13.6	0.8
28.....	0	....	14.4	....
30.....	2	.12	12.0	1.4
Total.....	177	11.06	....	100.3

* Location: S $\frac{1}{2}$ Sec. 26, T27N, R7E. MDM.
 Site quality: I-175
 Area of block: 320 acres
 Rust hazard: Medium

Date of field work: May 27, 1951
 Control cost: 2.5 man-days per acre
 Area of sample strip: 16 acres

ice, 1952). The most important of these is the effect of logging the mature stand on advance sugar pine regeneration. This can be determined only after logging has been completed. Hence, it is apparent that final selection of old-growth areas must wait until they have been converted to cutover status.

However, in practice it may be necessary to form preliminary judgments about old-growth areas in advance of cutting. In such instances, the advance regeneration now on the ground may provide a significant guide. Three general sorts of area may be recognized. First are areas which now have enough advance regeneration to qualify under the rating procedure outlined above, provided it is not destroyed by logging. Such areas obviously should be given priority

for sugar pine management. A second class of old-growth stand is one where there is little or no advance sugar pine regeneration and where, because of ground cover conditions, lack of seed sources, or other circumstances, there is little chance of securing additional sugar pine growing stock. Until such time as more adequate facilities for artificial regeneration become available, areas of this kind may well be excluded from sugar pine management planning. Finally, there is an intermediate class of stand, containing insufficient advance reproduction to qualify, but providing favorable opportunities for getting more sugar pine stocking when the old growth is harvested. Final decisions on this sort of area would depend on more detailed study than can be outlined here.

POLICIES FOR HANDLING THE SUGAR PINE RESOURCE

This survey of the sugar pine situation raises many questions. What sort of sugar pine program is in the public interest? Should public and private agencies spend more money or less money than they are now doing for perpetuation of the species? Do existing public policies and legislation contribute as effectively as possible to wise objectives in this phase of forest management?

Policy questions such as these involve a wide range of considerations, including many not introduced in an economic study. But, having recognized this, it is still apparent that economic forces should and do play an important role in policy formation. In view of this, we may well consider the implications for policy of the economic forces that we have just appraised, and formulate, at least tenta-

tively, certain recommendations as to the course which action on the sugar pine problem should take. To develop these implications and recommendations let us consider a number of rather specific problems in the field of sugar pine policy in the light of the economic appraisal we have made. In doing so we recognize that other, noneconomic, aspects of the situation may need consideration before final decisions are made.

Total expenditures

Past outlays. For almost twenty years, public and private agencies have been undertaking special expenditures to favor sugar pine. Although the total outlays have varied greatly from year to year, the total allotment of \$1,388,500 for blister rust control in the fiscal year

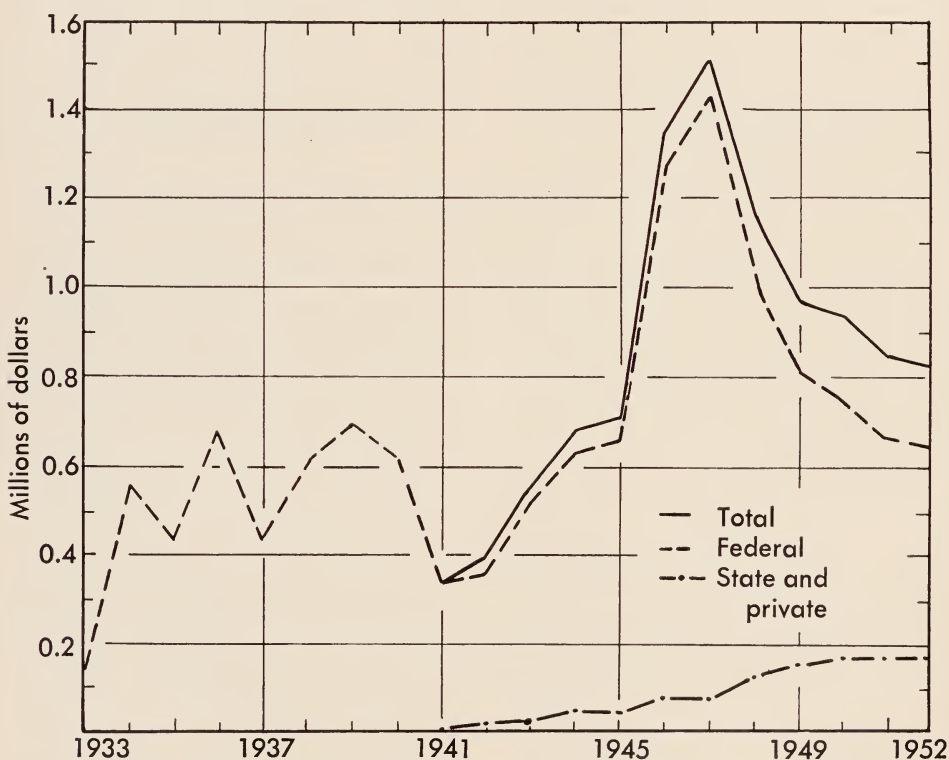


Fig. 18. Total expenditures for blister rust control on commercial forest land in California and Oregon, by calendar years.

1951 indicates that substantial outlays are involved (fig. 18). The total expenditure on special measures is probably somewhat greater than this. The United States Forest Service carries on a certain amount of stand improvement work and occasionally a private owner undertakes to prune crop trees or otherwise favor sugar pine. But, in the aggregate, these efforts over and above rust control are known to be small.

In recent years about one fourth of the total allotment has been for work on national park lands (U. S. Bur. Ent. and Plant Quar., 1951*d*). So the average expenditure on special measures on commercial sugar pine land has been in the neighborhood of \$1 million per year.

Cost of recommended program.

This aggregate level of expenditure appears to be economically justified in the light of our preceding analysis. As has been shown, it seems likely that sugar pine management may pay its way on some 230,000 acres of presently cutover land. If we were to place this area under sugar pine management immediately, going over the whole area during the next four years to establish blister rust control, and doing the necessary stand improvement and development work over the next decade, the annual cost during the next four years is estimated at \$950,000. In addition, about 60,000 acres of virgin sugar pine land is now being cut over each year. It is estimated that perhaps 12 to 13 per cent of this acreage would qualify for management under a \$50 per M sugar pine program. Protection and stand improvement work on this currently logged area would cost an estimated \$230,000 per year. Some preliminary disease control work would also have to be done on old-growth areas. Although this area would be relatively large, the cost per acre would be low. An estimated \$160,000 per year would be needed for this purpose.

The sum of the annual outlays just enumerated is \$1,340,000. Thus the cur-

rent \$1,000,000 per year outlay is somewhat below the total level of current expenditure, which seems justified in the light of economic analysis.

Purposes of expenditure

But the estimates just quoted are aggregate expenses for all of the several kinds of measures needed to grow sugar pine. Because sugar pine management is a complex job, it is just as important to allocate expenditure appropriately between such things as protection and stand improvement as it is to limit total outlays to the proper amount.

Optimum allocation of funds. Of the \$1,340,000 annual cost of a \$50 per M program, \$660,000 represents needed expenditures for disease control. The other half is for stand improvement, road development, and other measures of intensive management.

The optimum distribution of available funds among the various measures needed for sugar pine production is a matter of great importance. Cost per M of sugar pine produced rises rapidly if a proper balance of expenditure is not maintained.

For example, on Site I land with moderately dense sugar pine stocking now twenty to forty years old, and rust control costs of 1.5 man-days per acre, the average additional cost of growing sugar pine is \$25.40 per M board feet of yield, if management is carried out with properly diversified efforts on protection and stand improvement. However, if such areas receive blister rust protection but no other measures to facilitate sugar pine growth, the costs rise to \$55.50 per M board feet produced. The reason for this is that in the latter case we are paying to protect the entire stand from disease but, because we fail to prevent inroads of competing vegetation, part of the stand which is saved from the rust is lost to competitors.

We may look at the matter from a slightly different point of view. For the same stand, the costs of intensive sugar

pine management have a present worth of about \$49.50 per acre. They result in an estimated increase in sugar pine yields of 13,400 board feet per acre. If blister rust control alone were applied to this area, the present worth of the anticipated future costs would be only \$27 per acre. Hence, for every acre put under complete management, we could put 1.7 acres under disease protection alone. But protection alone would increase the estimated yield by only 4,800 board feet per acre. Thus \$49.50 spent in coördinated management of a single acre would increase yields by 13,400 board feet, but the same sum spent entirely for disease control would increase yields by only $1.7 \times 4,800$, or 8,200 board feet.

Needed increases in management. This critical dependence of efficiency on appropriate allocation of funds between protection and other management measures raises vital questions as to current sugar pine policy. As already noted, the great bulk of present special expenditure for sugar pine is directed toward disease protection. Although current expenditures for other management measures cannot be estimated, they are known to be extremely small. We must conclude, therefore, that a substantial increase is needed in outlays for stand improvement, road and other capital developments, and related measures designed to foster sugar pine growth.

Is a program of public action needed?

That a substantial investment of funds is required to grow sugar pine successfully is apparent. As has been shown, under appropriate circumstances such investments may be economically justified in the sense that, throughout the life of the crop, the principal of the investment will be returned along with adequate earnings. But this does not necessarily mean that such investments will automatically be forthcoming under existing economic conditions.

Obstacles to private investment.

In fact, the economic problem of sugar pine production is essentially that of how to secure the desired level of investment in the measures needed to grow sugar pine. In the present state of our economy and institutions, almost all investments in any kind of timber growing are prejudiced in comparison with other investment alternatives. This prejudice results from existing systems of taxation, insurance, credit, and land ownership. Because of defects in these institutions, investments in timber growing are currently less attractive to liquid capital than many other classes of investment of no greater basic economic merit.

Sugar pine shares this general disadvantaged position. In addition, the special problems of sugar pine production compound the disadvantage. The physical risks of sugar pine production appear to be greater than those for most other timber species, and this serves to intensify institutional obstacles to investment. For the economy as a whole, these risks are spread over a large area and over a variety of activities, so that they can be borne at reasonable cost. But for the individual investor they often represent insuperable obstacles to satisfactory financing of a program of sugar pine production.

For example, in our economic analysis, an interest rate of $2\frac{1}{2}$ per cent per year and a risk allowance of 25 per cent seemed appropriate from the standpoint of the economy as a whole. But because of the greater risks which individual investors would face, a 4 per cent rate of earnings is probably the smallest one which would attract any substantial amount of capital. Probably less than 40,000 acres of the best sugar pine land is productive enough to earn 4 per cent or more on the investment required for successful sugar pine production.

Thus, if the solution of the sugar pine problem is left to the operation of capital market forces as they work under exist-

ing financial institutions, our economy is practically certain to produce far less sugar pine than the 155 million board foot ultimate annual yield which has been suggested as a reasonable economic goal. To grow more, the institutional obstacles to investment in sugar pine production will have to be modified; that is, some sort of public program favoring the species will be needed.

Desirable lines of public action

Emphasize timber growing. We have already noted that, with minor exceptions, past public action has been directed solely at blister rust control. As a result, disease control has in the past been instituted on many areas without being followed up by the other measures needed to insure a sugar pine crop. Such situations illustrate the importance of proper formulation of objectives for public programs. Work on such areas has contributed substantially toward the objective of *disease control*. But some of it has contributed relatively little toward the more meaningful public goal of *growing more sugar pine*.

Encourage sugar pine production. Thus, one major modification of public action should be a reformulation of objectives. Rather than a public program of blister rust control, we need a public program to encourage sugar pine production. Public assistance in disease control is one of the major ways in which that end can be achieved. But it is important to distinguish the means from the ends.

National forest lands. If we recognize sugar pine production as the central aim, a number of modifications of existing programs immediately suggest themselves. On national forest lands, for example, it is virtually impossible to carry out a balanced program of sugar pine management because of the limitations which apply in the use of various types of public funds. Forest Service appropriations for blister rust control appear to be sufficient for the protective work needed under an economic program of

sugar pine production. But the Forest Service receives no appropriation for the stand improvement and other silvicultural measures which must complement protection if sugar pine is to be grown successfully. A certain amount of such work can be financed under provisions of the Knutsen-Vandenburg Act, but this applies only to lands currently being logged, and is of no help whatsoever on the great area of restocked cutovers which is the heart of the sugar pine resource.

Consequently, changes are needed which will permit the Forest Service to develop on its sugar pine lands an integrated program of sugar pine management. Only in this way can the present badly unbalanced situation be corrected.

Private lands. The situation on private lands is much more complex. About half of the most productive sugar pine land is in private ownership, and economic use of the resource requires that these privately owned areas be brought into production. The problem, of course, is one of stimulating the necessary investment in sugar pine production. To date, the public has been investing in these areas directly by assuming responsibility for disease control. But in so doing it has overlooked the coordinate need for investment in silvicultural development. Moreover, the possibility of encouraging private owners to share part of the investment burden has not been sufficiently recognized.

We have noted that, under existing institutions, investment in sugar pine production will not ordinarily be attractive to the private owner. But a different sort of public sugar pine program—a change in the institutional framework—might well encourage private investment. This would have the dual advantage of reducing the need for public financing and of giving the private owner a personal stake in the sugar pine program. Without such a stake his interest is negligible. With it, the efficiency in sugar

pine management on private lands might be considerably increased.

One essential feature required by such a reorientation would be to direct public aid at sugar pine growing, not just at disease protection. As in the case of National Forest land, aid to private owners should be aimed to produce more wood, not just to curtail the rust. It should be extended so as to encourage the undertaking of *all* the measures needed to mature a sugar pine crop.

A second important feature would be to get the land owner himself actively into the program.

There are numerous administrative devices which could conceivably be used to achieve these ends. This is not the place to evaluate each of these and to recommend a detailed procedure. But among the possible sorts of effort which seem worth study the following may be mentioned:

1. A program of public disease control under which an owner's land would receive protection only if he himself undertook the silvicultural measures needed to complement protection.

2. A system of carefully supervised

bounty payments payable to those land owners who put into effect and maintain an effective plan of sugar pine management, including both protective and silvicultural features.

3. A program of coöperative investment, under which the public would match (in some appropriate proportion) the private owner's investment in sugar pine management with a public investment on the owner's land.

Each of these alternatives has obvious disadvantages as well as advantages. Careful study of the administrative and economic problems involved in each would be needed before a wise choice could be made. It may well be that the desired results can be achieved by means other than those mentioned. But each alternative illustrates the essential features of a desirable program on private land—it must encourage direct participation and investment by the owner himself and it must insure that whatever sort of technical program is applied will be a balanced one, not a one-legged affair in which disease control or any other single facet of the sugar pine situation is given exclusive attention.

ECONOMIC SIGNIFICANCE OF THE SUGAR PINE RESOURCE

A wise program of public encouragement of sugar pine production can help to increase the net economic returns obtainable in the future from the pine forests of California and southern Oregon. These returns will not represent any huge bonanza in relation to the lumber economy of the West, but they should provide a satisfactory yield on the public and private investments which are required, and they will undoubtedly reflect more effective use of the resources that are available.

In addition, a sugar pine program provides a further sort of benefit not measurable in concrete terms, even though it is of considerable long-run economic sig-

nificance. The spectacular growth of the American economy and the relatively high standards of material living to which Americans have attained are due in no small measure to the magnitude and the diversity of the natural resources which have been available to us. Continued expansion of the economy depends, among other things, on the extent to which we maintain this substantial and diverse resource base.

Of the hundreds of natural resources which support our farms and industry, perhaps no single one is indispensable. We could get along without sugar pine or without any *one* other resource which might be mentioned. But we could not

get along satisfactorily if a quarter or a third of our resources were lost or destroyed. What may be true of one resource in isolation is not true of any substantial aggregate of resources.

Hence, the fact that sugar pine is not indispensable has no particular meaning for problems of conservation policy. The important question is not "Can we get along without it?", but rather "What will it do for us if we protect it?" On this ground the sugar pine resource has

tangible contributions to make, and these we have already analyzed. But beyond them, maintenance of sugar pine within the complex of our resource base contributes to one of the essential foundations on which our economy has been built—it helps to maintain both the variety and the quality of these resources. To allow it to disappear is to permit destruction of at least a small part of the root system essential to general economic survival and growth.

ACKNOWLEDGMENTS

The economic problems of sugar pine management have for several years concerned many individuals and agencies responsible for sugar pine resources. Out of a common concern for these economic problems grew a formal study which, during its later years, was carried on by the Agricultural Experiment Station, University of California. The information and analysis reported in the preceding pages had the advantage of a high degree of informal coöperation and exchange of information and ideas between a wide variety of interested people. The author therefore is heavily indebted to the following agencies and to many individuals on their staffs, although they are in no way responsible for the analysis and conclusions. These agencies are.

- California Forest and Range Experiment Station, United States Forest Service (under whose auspices the study was begun)
- California Division of Forestry
- California Forest Protective Association
- Office of Blister Rust Control, United States Bureau of Entomology and Plant Quarantine
- Region Five, United States Forest Service

Much of the primary information presented originated in the files of these agencies, and much of the analysis stemmed from numerous and informative discussions with their representatives.

APPENDIX A
Crop-tree Rating Tables

Tables A-1, A-2, and A-3 are on the following pages



Table A-1. Per cent of Marginal Stand Contributed by One Sugar Pine Crop Tree, by Present Tree d.b.h., Level of Control Cost, and Intensity of Rust Hazard (Site A-200—managed stand)

Present tree d.b.h.	Level of control cost														
	0-1.0 m.d./acre			1.1-2.0 m.d./acre			2.1-3.0 m.d./acre			3.1-4.0 m.d./acre			4.1-6.0 m.d./acre		
	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low
(inches)															
-2	25.6	22.5	17.7	15.6	13.7	10.8	11.0	9.7	7.6	8.2	7.3	5.7	6.0	5.2	4.1
2	30.4	25.5	19.0	18.5	15.5	11.6	13.1	11.0	8.2	9.8	8.2	6.1	7.1	5.9	4.4
4	37.0	29.6	21.2	22.5	18.0	12.9	15.9	12.7	9.1	11.9	9.5	6.8	8.6	6.9	4.9
6	45.0	34.2	23.2	27.4	20.8	14.1	19.3	14.7	9.9	14.5	11.0	7.4	10.5	8.0	5.4
8	53.4	38.1	23.9	32.5	23.2	14.6	22.9	16.4	10.3	17.2	12.3	7.7	12.4	8.9	5.6
10	63.8	41.9	26.6	38.8	25.5	16.2	27.4	18.0	11.4	20.5	13.5	8.5	14.8	9.7	6.2
12	74.7	48.1	31.8	45.5	29.3	19.4	32.0	20.6	13.6	24.0	15.4	10.2	17.4	11.2	7.4
14	81.4	52.5	35.4	49.6	31.9	21.5	34.9	22.5	15.2	26.2	16.9	11.4	18.9	12.2	8.2
16	87.0	55.5	42.2	53.0	33.8	25.7	37.3	23.8	18.1	28.0	17.8	13.6	22.9	9.8	
18	49.6	30.7	25.9	30.2	18.7	15.8	21.3	13.2	11.1	15.9	9.9	8.3	11.5	7.1	6.0
20	45.3	31.7	28.3	27.6	19.3	17.3	19.4	13.6	12.2	14.6	10.2	9.1	10.5	7.4	6.6
22	47.3	35.1	32.2	28.8	21.4	19.6	20.3	15.1	13.8	15.2	11.3	10.4	11.0	8.2	7.5
24	48.7	38.6	36.5	29.7	23.5	22.2	20.9	16.6	15.7	15.7	12.4	11.7	11.3	9.0	8.5
26	48.1	41.6	39.9	29.3	25.4	24.3	20.6	17.9	17.1	15.5	13.4	12.8	11.2	9.7	9.3
28	45.9	43.4	42.8	28.0	26.4	26.1	19.7	18.6	18.4	14.8	14.0	13.8	10.7	10.1	10.0
30	48.5	46.5	45.8	29.5	28.3	27.9	20.8	19.9	19.7	15.6	14.9	14.7	11.3	10.8	10.7
32	51.1	51.1	51.1	31.1	31.1	31.1	21.9	21.9	21.9	16.4	16.4	16.4	11.9	11.9	11.9
34	40.9	40.9	40.9	24.9	24.9	24.9	17.6	17.6	17.6	13.2	13.2	13.2	9.5	9.5	9.5
36	24.9	24.9	24.9	15.2	15.2	15.2	10.7	10.7	10.7	8.0	8.0	8.0	5.8	5.8	5.8

Note: In calculating the marginal rating of any stand, the aggregate percentage assigned to the larger trees must not exceed certain limits. These limits are as follows:

0-1.0 man days control cost:	Not more than 40% in trees	14% or larger on "Low" hazard.
1.1-2.0 man days control cost:	Not more than 25% in trees	24% or larger on "Medium" hazard.
2.1-3.0 man days control cost:	Not more than 17% in trees	28% or larger on "High" hazard.
3.1-4.0 man days control cost:	Not more than 13% in trees	
4.1-6.0 man days control cost:	Not more than 9% in trees	

Table A-2. Per cent of Marginal Stand Contributed by One Sugar Pine Crop Tree, by Present Tree d.b.h., Level of Control Cost, and Intensity of Rust Hazard
(Site 1-175—managed stand)

Present tree d.b.h.	Level of control cost														
	0-1.0 m.d./acre			1.1-2.0 m.d./acre			2.1-3.0 m.d./acre			3.1-4.0 m.d./acre			4.1-6.0 m.d./acre		
	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low
(inches)															
-2	11.7	10.3	8.1	7.1	6.3	4.9	5.0	4.4	3.5	3.8	3.3	2.6	2.7	2.4	1.9
2	14.9	12.5	9.4	9.1	7.6	5.7	6.4	5.4	4.0	4.8	4.0	3.0	3.5	2.9	2.3
4	18.7	14.8	10.5	11.4	9.0	6.4	8.0	6.4	4.5	6.0	4.8	3.4	4.4	3.4	2.4
6	24.4	18.7	12.8	14.9	11.4	7.8	10.5	8.0	5.5	7.9	6.0	4.1	5.7	4.3	3.0
8	28.7	20.6	13.1	17.4	12.6	8.0	12.3	8.9	5.6	9.2	6.6	4.2	6.7	4.8	3.1
10	38.0	25.3	16.6	23.1	15.4	10.8	16.3	10.9	7.1	12.2	8.1	5.3	8.8	5.9	3.8
12	45.6	30.3	20.9	27.8	18.4	12.7	19.6	13.0	9.0	14.7	9.7	6.7	10.6	7.0	4.9
14	51.5	34.4	24.3	31.4	21.0	14.8	22.1	14.8	10.4	16.6	11.1	7.8	12.0	8.0	5.6
16	57.8	38.5	30.4	35.2	23.4	18.5	24.8	16.5	13.1	18.6	12.4	9.8	13.4	9.0	7.1
18	31.5	20.2	17.4	19.2	12.3	10.6	13.5	8.7	7.5	10.1	6.5	5.6	7.3	4.7	4.0
20	32.6	24.0	21.9	19.8	14.6	13.3	14.0	10.3	9.4	10.5	7.7	7.0	7.6	5.6	5.1
22	34.4	26.7	24.9	20.9	16.2	15.2	14.7	11.4	10.7	11.0	8.6	8.0	8.0	6.2	5.8
24	35.4	29.1	27.8	21.5	17.7	16.9	15.2	12.5	11.9	11.4	9.4	8.9	8.2	6.8	6.5
26	31.7	30.7	31.7	21.8	19.3	18.7	15.4	13.6	13.2	11.5	10.2	9.9	8.3	7.4	7.1
28	33.6	33.6	33.6	20.4	20.4	20.4	14.4	14.4	14.4	10.8	10.8	10.8	7.8	7.8	7.8
30	27.9	27.9	27.9	17.0	17.0	17.0	12.0	12.0	12.0	9.0	9.0	9.0	6.5	6.5	6.5
32	15.0	15.0	15.0	9.2	9.2	9.2	6.5	6.5	6.5	4.8	4.8	4.8	3.5	3.5	3.5

Note: In calculating the marginal rating of any stand, the aggregate percentage assigned to the larger trees must not exceed certain limits. These limits are as follows:

Control	14" or larger on "Low" hazard.	24" or larger on "Medium" hazard.	28" or larger on "High" hazard.
0-1.0 man days control cost: Not more than 40% in trees			
1.1-2.0 man days control cost: Not more than 25% in trees			
2.1-3.0 man days control cost: Not more than 17% in trees			
3.1-4.0 man days control cost: Not more than 13% in trees			
4.1-6.0 man days control cost: Not more than 9% in trees			

Table A-3. Per cent of Marginal Stand Contributed by One Sugar Pine Crop Tree, by Present Tree d.b.h., Level of Control Cost, and Intensity of Rust Hazard
(Site II-150—managed stand)

Present tree d.b.h.	Level of control cost											
	0-1.0 m.d./acre			1.1-2.0 m.d./acre			2.1-3.0 m.d./acre			3.1-4.0 m.d./acre		
	High	Med.	Low	High	Med.	Low	High	Med.	Low	High	Med.	Low
(inches)												
-2.....	2.6	2.0	1.1	1.6	1.2	0.7	1.1	0.9	0.5	0.8	0.6	0.4
2.....	3.8	2.8	1.4	2.3	1.7	0.9	1.6	1.2	0.6	1.2	0.9	0.5
4.....	6.0	4.3	2.4	3.6	2.6	1.4	2.6	1.8	1.0	1.9	1.4	0.8
6.....	8.2	5.4	2.6	5.0	3.3	1.6	3.5	2.3	1.1	2.6	1.7	0.8
8.....	11.1	6.6	2.5	6.7	4.0	1.5	4.8	2.8	1.1	3.6	2.1	0.8
10.....	16.9	9.8	4.8	10.3	6.0	2.9	7.3	4.2	2.1	5.5	3.1	1.5
12.....	21.3	11.8	6.0	13.0	7.2	3.7	9.2	5.1	2.6	6.9	3.8	1.9
14.....	25.2	14.0	7.4	15.3	8.5	4.5	10.8	6.0	3.2	8.1	4.5	2.4
16.....	24.4	15.5	10.0	17.3	9.4	6.1	12.2	6.6	4.3	9.1	5.0	3.2
18.....	15.1	6.8	4.8	9.2	4.2	2.9	6.5	2.9	2.1	4.9	2.2	1.5
20.....	18.5	12.1	10.5	11.3	7.4	6.4	8.0	5.2	4.5	5.9	3.9	3.4
22.....	19.8	13.8	12.4	12.1	8.4	7.6	8.5	5.9	5.3	6.4	4.4	4.0
24.....	20.2	15.2	14.2	12.3	9.3	8.6	8.6	6.5	6.1	6.5	4.9	4.5
26.....	16.3	16.3	16.3	9.9	9.9	9.9	7.0	7.0	7.0	5.2	5.2	5.2
28.....	11.3	11.3	11.3	6.9	6.9	6.9	4.8	4.8	4.8	3.6	3.6	3.6
30.....												
32.....												
34.....												
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80.....												
82.....												
84.....												
86.....												
88.....												
90.....												
92.....												
94.....												
96.....												
98.....												
100.....												

Note: In calculating the marginal rating of any stand, the aggregate percentage assigned to the larger trees must not exceed certain limits. These limits are as follows:

0-1.0 man days control cost:	Not more than 40% in trees
1.1-2.0 man days control cost:	Not more than 25% in trees
2.1-3.0 man days control cost:	Not more than 17% in trees
3.1-4.0 man days control cost:	Not more than 13% in trees
4.1-6.0 man days control cost:	Not more than 9% in trees

14" or larger on "Low" hazard.
24" or larger on "Medium" hazard.
28" or larger on "High" hazard.

APPENDIX B

Statistical Analysis of Sugar Pine Demand

The tools of statistical analysis have frequently been applied to agricultural commodities (Schultz, 1938), but little effort has yet been made to use them in studying markets for wood. As the techniques used in this bulletin may thus be unfamiliar to many readers, a brief summary of procedures used in the statistical analysis of consumption may be of interest.

In its simplest form, the problem is to determine what relationship exists between the level of consumption in successive time periods, and the levels of those independent variables such as price, economic activity, and the like which logic indicates are important determinants of consumption. As there is usually more than one such independent variable, the method of multiple regression and correlation analysis is suited to the purpose.

In using this method, the form of the relationship must first be assumed; that is, whether the relation between independent and dependent variables is straight line, logarithmic, or of some other shape. Choice of form is ordinarily suggested by logical considerations. However, alternative forms may subsequently be tested by the method itself in order to determine which form provides the better fit to the available data.

After a given form of relationship has been chosen, an equation is fitted to time series data (such as those presented in Table B-1) by the method of least squares. The *normal equations* and other details of mathematical procedure may be obtained from Bruce and Schumacher (1950) or from any standard statistical textbook. The resultant multiple regression equation sums up all of the evidence provided by the basic data in a single mathematical statement. This shows in quantitative form the extent to which variation in the dependent variable is associated with variation in each independent variable.

For example, in the present case, straight-line relations between the several variables were initially selected on logical grounds. Solution for the constants of such an equation gave the expression

$$Y = 72.47 - 16.50 X_1 + 1.078 X_2 + 21.02 X_3$$

where the symbols are identified as in table B-1. Subsequent checks showed that a higher coefficient of multiple correlation was obtained with the straight line function than with semilogarithmic, logarithmic, or other logically defensible forms. The coefficient of multiple correlation, 0.77, indicates that about 60 per cent of the variation in Y is associated with variation in X_1 , X_2 , or X_3 . The coefficients of each of these terms indicate the change in Y, which was associated with a unit change in each independent variable when other independent variables are held constant.

The method of regression analysis thus provides a powerful tool for analyzing complex interrelationships between economic variables, and for expressing in simple quantitative form the average relationship found to exist between historical observations.

Table B-1 is on page 54

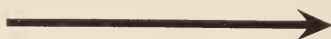


Table B-1. Consumption and Price of Sugar Pine Stumpage and Certain Related Economic Variables, 1910-1949*

Year	Consumption (MM bd ft) (Y)	Stumpage price/M (1926 dollars) (X ₁)	Gross national product (billion 1926 dollars) (X ₂)	Competition index (X ₃)
1910.....	105.3	\$6.11	52.1	3.17
1911.....	120.3	3.85	56.7	3.30
1912.....	135.0	5.09	55.7	3.12
1913.....	152.9	4.70	57.3	3.13
1914.....	138.9	4.39	56.5	3.53
1915.....	117.7	4.86	60.6	3.59
1916.....	169.3	4.12	55.9	4.05
1917.....	132.6	2.43	50.6	4.28
1918.....	111.8	2.59	49.9	4.36
1919.....	133.7	2.45	55.6	3.70
1920.....	146.0	3.26	55.8	4.95
1921.....	133.6	4.35	72.0	5.04
1922.....	194.1	3.92	75.0	5.45
1923.....	228.6	4.38	83.8	5.70
1924.....	245.7	4.33	85.0	5.57
1925.....	307.0	4.23	87.0	5.32
1926.....	306.5	4.50	95.3	5.93
1927.....	282.2	4.19	98.0	5.99
1928.....	305.9	3.36	98.9	5.71
1929.....	349.3	4.86	108.9	5.32
1930.....	205.2	7.33	105.2	5.80
1931.....	106.1	6.26	104.0	5.81
1932.....	47.7	5.73	90.0	6.70
1933.....		(complete data not available)		
1934.....	110.0	4.67	86.6	6.52
1935.....	192.8	3.88	90.3	6.96
1936.....	285.0	3.45	102.1	6.78
1937.....	319.2	3.28	104.5	6.85
1938.....	267.1	4.53	107.8	6.74
1939.....	308.9	4.06	118.4	6.68
1940.....	363.0	3.88	129.0	6.74
1941.....	369.9	3.91	144.7	6.93
1942.....	338.4	4.82	163.5	6.41
1943.....	277.9	4.03	188.5	6.85
1944.....	317.8	5.03	205.5	7.50
1945.....	228.1	6.91	203.4	8.04
1946.....	344.0	5.96	174.3	7.37
1947.....	343.2	8.24	153.4	9.63
1948.....	315.0	10.60	156.9	10.97
1949.....	311.8	12.48	164.9	11.84

* For definitions and sources, see text pp. 21-22.

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